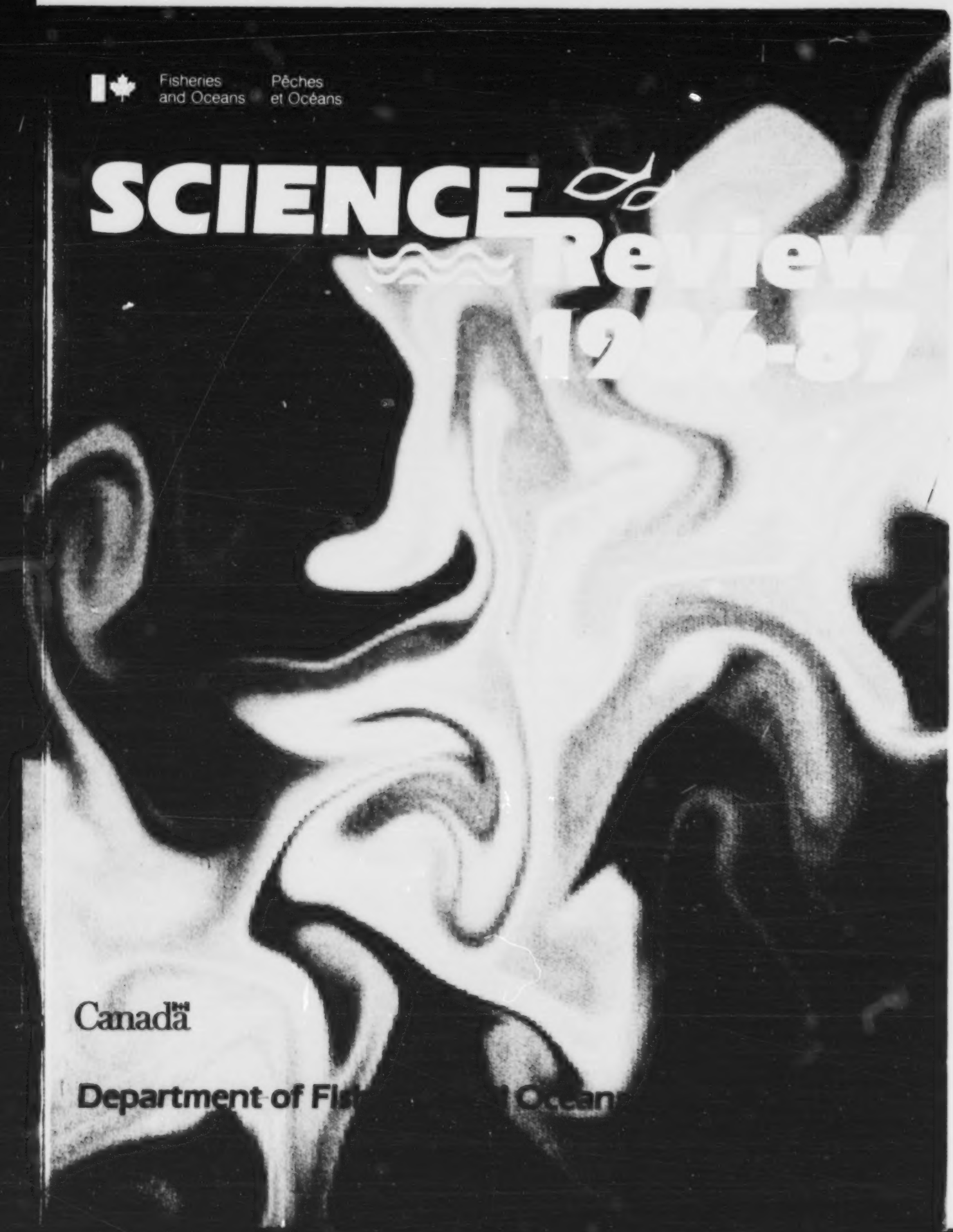
Fisheries and Oceans | Pêches et Océans

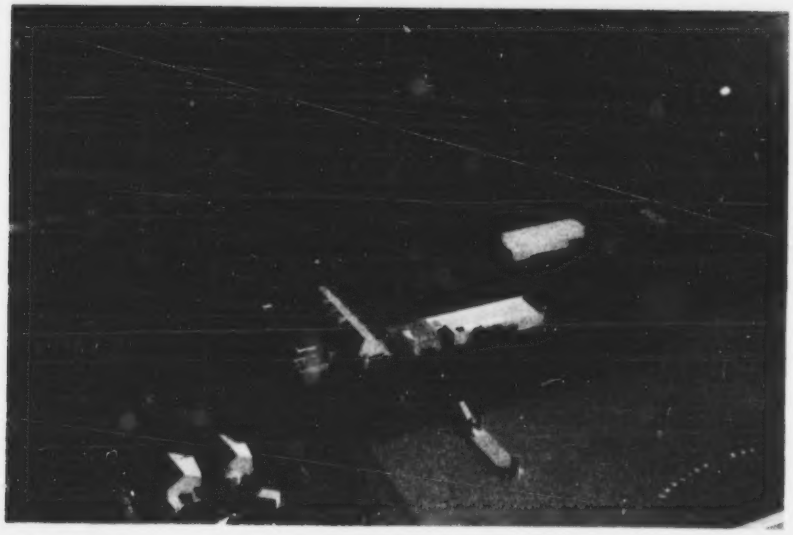
SCIENCE



Canada

Department of Fi[illegible] Ocean[illegible]

SCIENCE Review 1986-87



Institute of Ocean Sciences, Pacific Biological Station and a model of the almost-complete West Vancouver Laboratory.

Fisheries and Oceans | Pêches et Océans

SCIENCE Review 1986-87

Canada

Department of Fisheries and Oceans, Pacific Region

DFO/4026
Fs 1-45/1987E
ISBN 0-662-15757-5

This report describes the programs and activities of the Science Sector, Pacific Region, Department of Fisheries and Oceans during the fiscal year 1986/87.

It is intended to review the activities of Biological Sciences Branch (headquartered at the Pacific Biological Station with facilities at West Vancouver, Cultus Lake and the Institute of Ocean Sciences) and Hydrography and Physical and Chemical Sciences at the Institute of Ocean Sciences (IOS).

This new publication, which follows a re-structuring within the Department, replaces previous annual reviews from the individual establishments.

Science Review 1986/87 was produced by Communications Branch, Pacific Region; Kelly Francis and Kate Glover, editors.

FRONT COVER: *Advances in high resolution computer modelling of eddy fields make possible simulated ocean colour images which resemble the complex nature of the ocean as seen in satellite or aircraft photographs.*

BACK COVER: *The flow field that induces a colour field (front cover) is revealed by contours of sea surface elevation. White contours denote positive elevations; black contours denote depressions. Under the influence of the earth's rotation, water tends to flow clockwise about elevations and counterclockwise about depressions (in the northern hemisphere).*

For additional copies or further information, please write:

Institute of Ocean Sciences
P.O. Box 6000
9860 West Saanich Road
Sidney, British Columbia
Canada V8L 4B2

Pacific Biological Station
Hammond Bay Road
Nanaimo
British Columbia
Canada V9R 5K6

Contents

Introduction	7
INSTITUTE OF OCEAN SCIENCES	9
Hydrography	11
Field Hydrography	11
Marine Cartography	13
Tides and Currents	14
Engineering Services	17
Physical and Chemical Sciences	20
Ocean Physics	20
Fjords	20
Continental Shelves	21
Large Scale Circulation and Climate	23
Upper Layer Processes	26
Forecast Development	27
Instrumentation and Observational Techniques	28
Ocean Chemistry	29
Centre for Ocean Climate Chemistry	30
Pollution	31
Ocean Flux	32
Acid Rain	33
Beaufort Sea Oceanography	33
Ocean Ecology (See Biological Sciences)	36
Data Assessment	36
BIOLOGICAL SCIENCES BRANCH	39
Salmon and International	42
Fish Age Determination	51
Groundfish	53
Shellfish	61
Herring	66
Ocean Ecology	69
Recruitment Mechanisms	73
Fish Health and Parasitology	80
Fish Culture	83
Habitat Capacity	89

Science and Survey Support 93

Ships 93
Computing 96
Communications 97
Management Services Branch/Comptroller's Branch 99

Appendices
I Publications 100
Institute of Ocean Sciences 100
Biological Sciences Branch 106

II Permanent Staff 121

Introduction

During 1986-87 a reorganization took place within the Department of Fisheries and Oceans (DFO) which resulted in six regions across the country and major changes to the management structure. A new science organization was created under an Assistant Deputy Minister with the full spectrum of science activities in each of the regions headed by a Regional Director of Science.

The restructured science organization for Pacific Region is shown at the back of this review. The former Ocean Science and Surveys component at the Institute of Ocean Sciences (IOS), Sidney, and biological sciences activities at the Pacific Biological Station (PBS), Nanaimo and satellite stations at West Vancouver and elsewhere now report through branch directors to the Regional Director of Science; who, in turn, is directly accountable to the department's Regional Director General. Additionally, strong linkages to the ADM Science and the departmental science community across Canada are maintained.

Other changes include the creation of two Centres of Disciplinary Expertise (CODES) in Pacific Region. These centres highlight specific activities of national significance in our science program and are intended to provide a focus for research effort on priority issues. The CODES for Pacific Region are concerned with Genetics and Biotechnology research (at West Vancouver Laboratory and PBS) to aid both the department's enhancement initiatives and the aquaculture industry, and the Chemical Climate research activity at IOS associated with the study of the "Greenhouse Effect" and the ocean's role in climate chemistry.

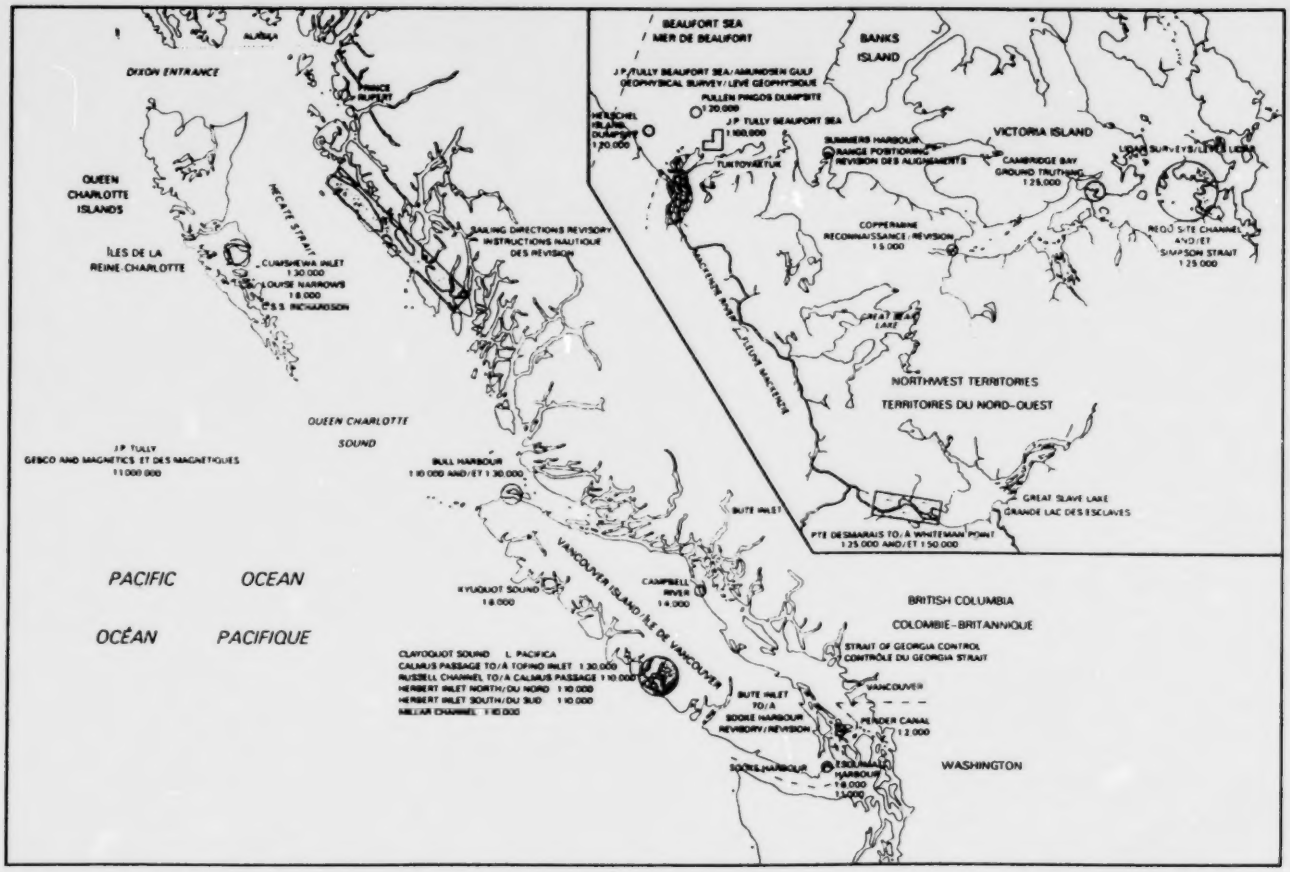
Other structural changes in DFO Pacific Region consolidated financial, personnel and other support functions in Vancouver headquarters while the vessel management and related operations for both science and enforcement activities were centralized at IOS. Expansion of vessel berthage and depot facilities is underway. Finally, the construction of the new West Vancouver Laboratory facility was started during the year with completion expected early in 1988. This facility will serve as a centre for habitat, lake enrichment, recruitment mechanisms and genetics, biotechnology and fish culture research and will be a welcome addition to the region.

The science-related needs and concerns of the department's clients will continue to be addressed in accordance with government policies and priorities under the new science organization. Programs will focus on a commitment to longer-term, targetted basic research, topical issues and, where appropriate, multidisciplinary research projects. Vigorous oceanographic, hydrographic and biological programs will be maintained with emphasis on scientific excellence, expansion of scientific knowledge, and provision of scientific assessment and advice.

Noteworthy in 1986 was the retirement of Dr. Cedric R. Mann as Director-General at the Institute of Ocean Sciences. His influence though was not limited to Vancouver

Island, or indeed the west coast. Dr. Mann had been Director-General at the Bedford Institute of Oceanography, and prior to that had been a senior oceanographer and then Director of the Atlantic Oceanographic Laboratory. His scientific work in the areas of ocean circulation and dynamics, carried out in the Atlantic and in the Antarctic, is still relevant today. His knowledge of science and his vision for oceanography led him to organize the Hudson 1970 circumnavigation of the Americas, to promote the participation of university, industry and government scientists in the Canadian Meteorological and Oceanographic Society (formerly Canadian Meteorological Society), to inspire Canadian oceanographers to direct their attention to much needed work on the continental shelves, and most latterly, to become a prominent Canadian spokesman and advocate for the oceanographic aspects of world climate research. Valued not only as a scientist but as a science administrator, from 1979 to 1986 he quietly but firmly led IOS towards his goal of a mature, high quality scientific establishment.

INSTITUTE OF OCEAN SCIENCES



Pacific Region 1986 hydrographic program.

Hydrography

Canadian Hydrographic Service, Pacific Region, has responsibility for surveying the Pacific coast of Canada, the waters of the western Arctic and inland navigable waters as far east as the Saskatchewan/Manitoba border. In addition to nautical charts, CHS also publishes related publications including tide tables and sailing directions. Tidal and current surveys are also carried out to ensure that reliable data for tidal predictions and other specific purposes are available. Also included in the regional mandate is instrument development and industrial liaison.

Among the highlights of the year was the publication of Chart 3312, a new format Cruising Atlas for Desolation Sound and Jervis Inlet. Introduced at a reception onboard the CSS JOHN P. TULLY at Expo 86, sales figures and positive response from chart users indicate general acceptance of this new product by recreational boaters. In August, the submersible PISCES IV was reunited with PANDORA II for a very successful deep dive program on the hydrothermal vents at Axial Seamount. The program was a joint venture with scientists from DFO, EMR, University of Victoria and NOAA, who supplied the ship. A tsunami on May 7, 1986 tested the Region's warning system. While the wave arrived on schedule, its amplitude was insignificant.

Field Hydrography

Changes to traffic routes, types and sizes of vessels, harbours, bottom topography and coastline require new surveys or resurvey. In 1986/87, the field hydrography program involved surveys on the Pacific coast as well as in the Arctic.

The major coastal survey party was assigned to the barge L. PACIFICA, from April to October for continuation of the 1985 surveys in the Tofino inlets complex. By the end of the season surveys of Tofino Inlet, Bedwell Sound, Calmus Passage, Russell Channel, Herbert Inlet, the inshore portion of Clayoquot Sound and part of Millar Channel had been completed. (*Contact: J.V. Crowley*)

CSS JOHN P. TULLY continued surveys in the Beaufort Sea north of Tuktoyaktuk. This was a favourable ice year and good progress was made on this project. Two potential dump sites were surveyed for the Environmental Protection Service (EPS), and, in co-operation with staff from the Atlantic Geoscience Centre (AGC), further geophysical surveys linking previous work in the Mackenzie Bay area to those in the

entrance to Amundsen Gulf were carried out. (*Contact: M.V. Woods, IOS or S. Blasco, AGC.)*

GEBCO (General Bathymetric Chart of the Oceans) magnetic, XBT (Expendable Bathythermograph) and SAIL (Serial ASCII Instrument Loop) data were logged on passage to and from the Arctic as part of an ongoing program. (*Contact: M.V. Woods.*)

A detached party from CSS JOHN P. TULLY assisted the Canadian Coast Guard (CCG) by carrying out a reconnaissance survey of the approach to the Coppermine dock and by positioning the range markers at Summers Harbour. (*Contact: A.R. Raymond.)*

At the request of PBS, a shore party carried out a survey of the Campbell River estuary. (*Contact: M.M. Ward.*) In addition, a large-scale survey of the Pender Canal was completed for new charting action. (*Contact: E.D. Sargent.*) Revisory surveys of Bute Inlet and the southern portion of the Gulf of Georgia were conducted. (*Contact: R.M. Hare.*) A large-scale survey of the areas adjacent to the IOS wharves was made as part of a feasibility study for proposed expansion of these facilities. (*Contact: C.L. Nowak.*)

Under contract, a Light Detection And Ranging (LIDAR) survey was carried out in Simpson Strait and Requisite Channel as was ground truthing of the 1985 LIDAR survey of Cambridge Bay. (*Contact: B.M. Lusk.*)

Contract surveys of Bull Harbour and Nahwitti Bar were carried out on the coast and on the Mackenzie River from Great Slave Lake to Morrissey Creek. (*Contact: B.M. Lusk.*)

Early in 1987 new aerial photography was obtained and a coastline plot produced, under contract, for the 1987 resurvey of Vancouver Harbour. *(Contact: B.M. Lusk.)*

Sailing Directions

The sixth edition of the *Small Craft Guide, Boundary Bay to Cortes Island (Volume II)* was published in April and the fourth edition of *Arctic Canada Sailing Directions (Volume III)* was published in July. New information, photography and diagrams were incorporated into these editions.

Field inspection was carried out for revisions to a portion of *B.C. Sailing Directions, Volume II (North Portion)* and new photography for the Fraser River and Vancouver Harbour was obtained for *B.C. Sailing Directions, Volume I.*

Marine Cartography

The major accomplishment of Chart Production during the year was the release in April of a special recreational boaters' atlas of twenty-nine chartlets produced as Chart 3312 for the Jervis Inlet and Desolation Sound area. In all, nineteen New Charts were released in Pacific Region. Eight of these were New Charts of the Western Arctic which were produced under contract in 1985/86 for printing in 1986/87. A further seventeen charts were produced on contract for printing in 1987/88. Sixty-eight New Edition charts were produced which included the 1986 and 1987 editions of the Mackenzie River strip charts. Twenty-three Reprints, including two at Headquarters, four chart amendment patches and one overprint edition were also produced and released.

The Hydrographic Data Centre processed 501 plans, 623 MAREP forms (from the Canadian Power Squadron's Marine Reporting Program) and fulfilled seventy-one survey document requests.

There were 127 Notices to Mariners and six Notices to Shipping issued along with the necessary chart amendment tracings.

The Chart Amendment staff applied corrections to 160,000 individual charts and the Chart Sales Office distributed 154,415 charts, 70,475 publications and 29,184 information brochures during the year.

Chart Production continued to provide support services to the Institute with approximately 350 miscellaneous projects being completed for the reporting period.

Automated Cartography continued to be a very productive area requiring extra shifts to meet production schedules. Both digitizing tables and editing stations were used in two shifts during peak periods. During the year over 300 plots were produced on the Kongsburg plotter.

Outside education and promotional activities were limited this year to our participation in the Vancouver Boat Show. However, numerous tours and lectures were provided to Canadian Power and Sail Squadron members and boating course students on site at IOS.

Chart #	New Charts Released in 86/87	Scale
3053	Shuswap Lake	1:50,000
3312	Jervis Inlet and/et Desolation Sound	various
3538	Desolation Sound and/et Sutil Channel	1:40,000
3539	Discovery Passage	1:40,000

3541	Approaches to/Approches à Toba Inlet	1:40,000
3542	Bute Inlet	1:40,000
3543	Cordero Channel	1:40,000
3552	Seymour Inlet and/et Belize Inlet	1:50,000
3685	Tofino	1:20,000
3890	Approaches to/Approches à Skidegate Inlet	1:40,000
3958	Prince Rupert Harbour	1:20,000
7661	Demarcation Bay to/ Phillips Bay	1:150,000
7662	Mackenzie Bay	1:150,000
7663	Kugmallit Bay	1:150,000
7664	Liverpool Bay	1:150,000
7665	Franklin Bay and/et Darnley Bay	1:150,000
7666	Cape Lyon to/à Tinney Point	1:150,000
7667	Dolphin and Union Strait to/à Prince Albert Sound	1:150,000
7685	Tuktoyaktuk Harbour	1:15,000

Tides and Currents

Pacific Region of the Canadian Hydrographic Service conducts, or arranges, the maintenance of 16 permanent tide gauging stations on the Pacific Coast and five permanent stations in the western Arctic. In addition, four temporary gauging stations are operated on the Pacific Coast on a continuing basis and several temporary gauges were located on both coasts during hydrographic surveys.

Pacific Region also operates and maintains Canada's share of the Pacific Tsunami Warning Net, which consists of warning gauges at Bamfield, Tofino and Langara Island.

Acquisition and processing of data from permanent and temporary gauging was on schedule with 98.6% data recovery. Processed and digitized records are sent to the Marine Environmental Data Service (MEDS) on an on-going basis, with a lag time of about two months. The record from analogue gauges in the western Arctic was collated and processed, but was not forwarded to MEDS due to its poor quality. Pressure gauges and barometers have been operated in conjunction with analogue instruments in the Arctic for the past several years. The record from these gauges has been completely collated and will be forwarded to MEDS.

Data from gauges at Campbell River, Nanoose Harbour, Gold River, and Zeballos were also used in a study of crustal movement on Vancouver Island, carried out jointly with the Pacific Geoscience Centre (PGC). The record from three perma-

nent gauges were processed preferentially and daily and monthly mean sea levels were transmitted to Dr. Wyrtki of the University of Hawaii, to fulfill Canada's commitment to the Integrated Global Ocean Station System (IGOSS). (*Contact: F.E. Stephenson.*)

The staff of Tides and Currents and tsunami warning gauges received a severe test of their readiness to respond on May 7, 1986, when an earthquake (measured at 7.7 on the Richter scale) south of Adak in the Aleutian Islands caused the Alaska Tsunami Warning Center to issue a warning for an impending tsunami on the Canadian and U.S. coasts. While response by the Tides and Currents staff was immediate, the instrument response could not be measured since fortunately the tsunami did not appear. However, our cooperation with other scientists, B.C. Provincial Emergency Program, Emergency Preparedness Canada and communication with the media was tested and found to be satisfactory. (*Contact: W.J. Rapatz.*)

Surveys of the currents in hazardous and fast-flowing narrow passes on the British Columbia coast, using a combination of pressure gauges, real-time observations and current measurement, have been successful and are being continued. Four new current reference stations and significant improvement of an existing reference station in the 1987 Tide and Current Tables are a result of these surveys. Preparations for a current survey of Okisollo Channel, Yuculta Rapids, Arran Rapids and Seymour Narrows in 1987/88 were completed. (*Contact: M.J. Woodward.*)

In June, a cruise on CSS PARIZEAU to measure surface currents in the Tully Eddy off Vancouver Island was carried out. CSS PARIZEAU was also used in October/November to make surface current and CTD (conductivity-temperature-depth) measurements at specific locations in Dixon Entrance, where more information was needed to draw meaningful conclusions about tidal and non-tidal current patterns in this area. Three motion picture sequences were made of currents at variable depths in Dixon Entrance and Hecate Strait which will assist in describing the complicated and quickly changing patterns. (*Contact: W.S. Huggett, W.R. Crawford.*)

Work continued on numerical models of the Fraser River and Campbell River estuaries. In the Fraser further measurements were made at the trifurcation near New Westminster. Prediction and hindcasting of water surface elevations and currents were provided to many agencies upon request. Preparations have been made to include the residence times of pollutants into the prediction model. In the Campbell River estuary the field phase of a study to determine the impact of an environmental enhancement project on salmonid feeding grounds was completed. The numerical model including the salinity intrusion, is underway. (*Contact: A.B. Ages.*)

In the Canadian Arctic a reconnaissance survey to determine the feasibility of current surveys in Simpson and Bellot Straits was carried out. Tide gauges in the Queen Elizabeth Islands and in Pond Inlet, which were deployed five years ago and serviced annually, were recovered for the last time in 1986.

Approximately 300 requests for information on tides, currents, water levels or bench marks from professional or commercial groups were answered, as well as numerous

additional requests from the general public. The tsunami of May 7, provoked approximately 250 telephone calls in a two-hour time period.

Tidal and Current information was provided for 28 new charts, 34 new edition charts and two editions of Sailing Directions. Datum checks were made on 92 field sheets or other hydrographic documents.

Diving Unit

In 1986 the eleven certified divers at IOS carried out 78 dives on the Pacific coast or in the western Arctic.

In order to fulfill the objectives of these 78 dives, the divers entered the water 140 times spending 62.3 hours (over 2 1/2 days) engaged in a variety of tasks including deployment, recovery and repair of instrumentation.

The largest project was a tide and current study in the area of Stuart Island. Approximately half of the diving carried out in 1986 was in support of this project. Sites were selected, anchors deployed and pressure gauges installed during cruises in June and November. The many strong currents in this area meant that these dives had to be carefully planned.

The most challenging project was the Acoustic Scintillation Project, carried out in Cordova Channel, which took place over a two-week period in October. Ten of the Institute's divers participated. The acoustic system tripods and signal cables were deployed on both sides of the channel and three sub-surface moorings containing six current meters were deployed in the channel. The divers assisted with the positioning and alignment of the tripods and with the recovery and redeployment of one of the electronics packages. They also helped to ensure valid current meter data were obtained by removing kelp from the current meters several times during the project.

Institute divers also conducted underwater inspections of the TULLY, PARIZEAU, TANU and RICHARDSON, launched two controlled ecosystem experiment bags in Patricia Bay and carried out shoal examinations at Bedwell Harbour and Port Browning.

The organization of the many DFO dive units changed slightly in 1986. Regional Diving Control Boards were established to give each Region some measure of autonomy. In the Pacific Region the new Diving Control Board consists of four diving officers from various branches or institutes. Within the Department there is, however, overall compliance with the Canadian Association for Underwater Science's (CAUS) "Standard of Practice for Scientific Diving". Also, the new "DFO Manual for Diving Safety" is presently being prepared using CAUS standards as a guide. This manual is expected to be available in 1987. (*Contact: F.E. Stephenson.*)

Engineering Services

The group provides electronic and mechanical engineering and electronics support for hydrographic surveys, oceanographic research and ship operations. Industrial Liaison also operates from within the group, promoting the established Contracting-Out policy and interaction between IOS, other government departments and the private sector. (*Contact: T.A. Curran.*)

Institute Electronics

Activities such as calibration, repair, installation and routine maintenance of equipment in support of hydrographic and oceanographic programs and ship operations were successfully performed during the year. The major equipment areas were radios, depth sounders and digitizers, positioning systems and data loggers.

Ships, launches, the barges PENDER and L. PACIFICA were fitted out for hydrographic purposes. Field support was provided for a Beaufort Sea survey on the TULLY, and support was provided from IOS to local survey parties. (*Contact: E.W. Hinds.*)

Engineering Development

This group provides custom development of hydrographic and oceanographic instrument systems and a consulting service to all IOS groups.

Development of expertise in underwater acoustical engineering continued to be a priority for both in-house projects and for management of government-funded contracts with private industry. A facility for calibration of underwater transducers was completed, permitting accurate calibration of most projectors and hydrophones over the range 10kHz to 700kHz. A number of building block modules for processing acoustic signals have been developed to ease implementation of system concepts and were applied to various projects such as an Acoustic Telemetry System which provides a method to transmit colour video imagery from the sea floor to the surface over a narrowbeam acoustic link. A contract to develop an ice motion detector and tracker as part of a Correlation Sonar Project was completed, as was a contract for Acoustic Release development.

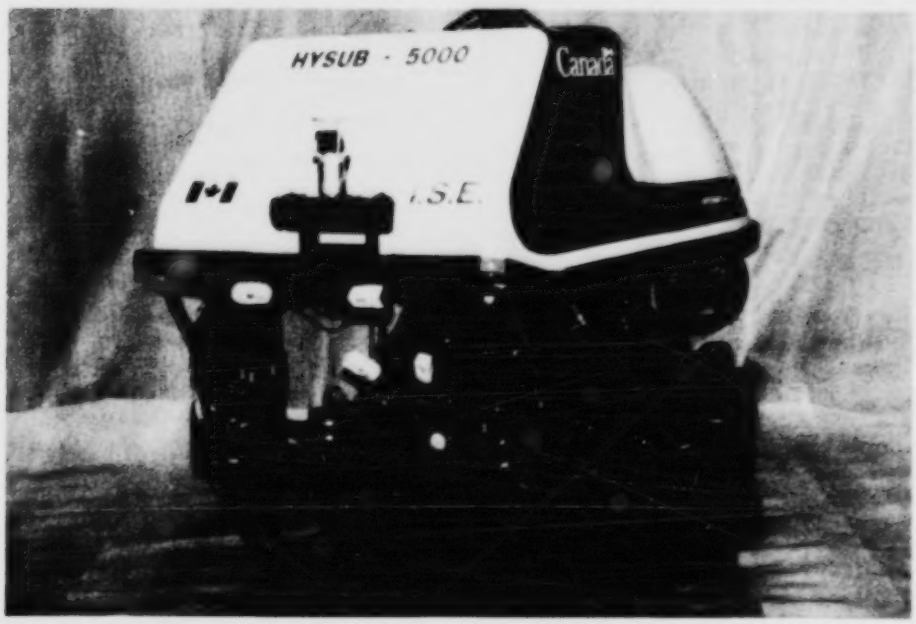
Repairs to specialized ship's sonar equipment were executed and acoustical engin-

eering advice was provided to other IOS and PBS groups on a frequent basis.

Field support was provided for initial deployment of instruments previously developed within the group such as the real-time Telemetering Tide Gauge used by hydrographic field parties, the Meteorburst Telemetry System used to collect tidal information from remote sites, and the turbidity sensor and logger used to measure episodic events in sediment outfall areas. The Active Drifter was deployed to collect engineering data on system operation and has been turned over to private industry for further improvements.

Contract management was provided for the Larsen Project which applies a LIDAR laser system to measure depth of water at high speed from a low flying aircraft. The group developed a motor controller to rotate the laser mirror and an optimized high speed logarithmic amplifier which significantly improved depth surveying results. A search for an improved laser is underway.

The contracted development of a Remotely Operated Vehicle (ROV) capable of operation to a depth of 5000 metres, which is currently the world's deepest diving ROV, was managed effectively. A contract was let for development of new data acquisition and archiving software for SAIL, DFO's shipboard data system, extensively used on IOS ships and now an international standard. (*Contact: J. Galloway.*)



Hysub 5000, the ROV (Remotely Operated Vehicle) under development by I.S.E. for DFO. Due for delivery in early 1988, the ROV will work to depths of 5000 metres with the capability for high quality data transmission.

Industrial Liaison and Contracting

In addition to contracting out directly, IOS participates in such government ventures as the Unsolicited Proposals (UP) program with the Department of Supply and Services (DSS) and the Industrial Research Assistance Program (IRAP) with the National Research Council. The UP program facilitates proposals originating in the private sector, with benefits to the company and to IOS. The IRAP program assists technology transfer from government labs, such as IOS, to industry. Typically IRAP grants are for 50 percent of the project cost, with the remainder coming from industry.

Increasingly, there is concern from the private sector regarding manufacturing rights and protection of fundamental technology developed in the labs prior to adoption by industry. The crown corporation, Canada Patents and Development Limited (CPDL), can provide this assurance and IOS is presently transferring administration and control of several technologies to CPDL. (*Contact: T.A. Curran.*)

Physical and Chemical Sciences

Ocean Physics

The scientific program of the Ocean Physics Division covers a wide range of topics, reflecting the diverse geography and ocean activity on the Pacific and Arctic coasts. During the period covered by this report emphasis was on improving the description and understanding of ocean conditions on the Pacific and Beaufort Sea continental shelves, and on application of the resulting information to the prediction of fish stock recruitment and ice motion. Other areas of special attention included theoretical studies directed towards improving modelling of the large scale ocean circulation in preparation for planned international experiments, development of new observational tools using acoustic techniques and the improvement of weather and sea-state forecasting on the Pacific coast in co-operation with the Department of Environment and Ministry of Transport.

Fjords

Much development on the Pacific Coast takes place on the shores of fjords and narrow passages which are the habitat of migrating and resident stocks of fish and other marine life. They are also increasingly being identified as sites of aquaculture operations. There is a need to predict the impact of industrial development on water quality and marine life. This requires prediction of the eventual distribution of any deleterious substances originating with the development which in turn requires a knowledge of the typical and extreme currents and mixing conditions; typical and extreme levels of natural properties and substances, such as dissolved oxygen; and the physical and chemical behaviour of both natural and introduced substances. Currents and mixing in fjords and narrow channels are a result of the combined effects of tides, winds, runoff and conditions at the fjord mouth. The main scientific obstacle to general models for estimating currents and vertical structure is lack of understanding of the sites and amount of mixing in relation to the vertical structure and currents.

One approach to this problem is the study of the rates and processes of mixing under various conditions of flow and stratification through direct field and laboratory turbulence measurements. A freely-falling instrument has been developed for this purpose, and has provided profiles of turbulence in stratified (Sansum Narrows) and fully mixed (Haro Strait) channels, with visualisations being provided by high frequency echo sounding. (*Contact: A.E. Gargett.*)

Another approach to understanding the role of mixing in fjords is through careful analysis of differences in the overall water property distributions in the different fjords found on the coast. There is a wide range of sill depths, tidal heights and freshwater inputs. Historical data were used to estimate vertical mixing by the rate of change of dissolved oxygen in deep water, revealing some systematic groupings of inlets. (*Contact: D. Stucchi.*) A project was begun jointly with the University of British Columbia to compare direct measurements of turbulence intensity with estimates of mixing based on water property profiles. (*Contact: A.E. Gargett.*)

In response to recurring episodes of dissolved oxygen depletion in the upper layers of Neroutsos Inlet, and attendant conflicts over the discharge of pulp mill effluent and the survival of local salmon and herring stocks, an observational program was undertaken. The objective is to determine which processes are important in controlling oxygen levels to provide some indication of the potential effectiveness of various schemes for reducing the impact of effluent discharge. The field portion of the study will end in October 1987. (*Contact: D. Stucchi.*)

Continental Shelves

The major emphasis in the physical oceanography program is on the continental shelves. This is a reflection of Canada's responsibility for management of the area and of the role which scientific knowledge may play in boundary and sovereignty issues.

A simple overview description of the currents and water properties of the Pacific continental shelf can be expected to be completed in the near future, while three or four more years will be required to achieve the same level of understanding of the Beaufort Sea. Preliminary data are available for the channels of the Northwest Passage. However, improved understanding of processes and their balance is required for predictive models and to understand and apply the results from monitoring systems such as the shorestation sampling program. The present strategy is to design and conduct observational experiments to determine what controls the major features, to use computer modelling in experiment design and interpretation, and in extrapolation of results to other situations, and to apply current understanding to practical problems.

The large-scale descriptive survey of the Pacific continental shelf, conducted in cooperation with the Tides and Currents Section of Hydrography, began in 1978 southwest of Vancouver Island and has gradually worked northward. In some years

it has consumed most of the ship time and current meters available for Pacific oceanography. It has also permitted the planning of process-oriented experiments. (*Contact: R.E. Thomson.*)

One of the process-oriented experiments stimulated by the general survey was the CODE-II experiment. Analysis of data from the 1984 field program indicated that the "Juan de Fuca eddy" is not always present even though its formation appears to be favoured by the flow field set up by the opposition of the outflow from Juan de Fuca Strait and the summertime southward current along the outer edge of the continental shelf. (*Contact: H.J. Freeland.*)

The 1982-83 El-Nino precipitated a renewed interest in the effects of oceanic variability on regional fish stocks. Daily measurements of surface seawater temperature and, in some locations, salinity have been taken at 15 coastal locations for many years. (*Contact: L.F. Giovando.*) These provide an essential indication of the climatological conditions, but cannot be understood in detail without a better understanding of the nature of the signals observed. Drawing on the knowledge gained through the large scale continental shelf survey, a ten-year field program has been established in co-operation with Biological Sciences Branch to obtain a more adequate description of oceanic variability in the area of La Perouse Bank for use in studies of the variability of sablefish and herring populations. This involves the maintenance of three current meter moorings and the completion of a grid of CTD and plankton stations several times a year. During 1986/87 the grid was completed ten times. (*Contact: R.E. Thomson.*)

The La Perouse project is itself expected to provide background information for a new Marine Survival of Salmon (MASS) program aimed at improving understanding of the factors affecting the marine survival of chinook and coho salmon in Barkley Sound and over the adjacent continental shelf. The new program is scheduled to begin in 1987, again in co-operation with the BSB, and will continue for three years. It involves physical oceanographic studies of Barkley Sound, the Vancouver Island Coastal Current and eddies over Swiftsure and Amphitrite Banks. Tidal models of several sorts are being developed for use in the experiment. (*Contact: M. Healey, PBS.*)

The Panel on Energy Research and Development (PERD) is sponsoring work in the Beaufort Sea to improve the oceanographic input to models for predicting ice motion. This has required a significant improvement in understanding of the current systems in the area and their response to atmospheric forcing. An array of 16 current meter moorings was installed through the ice in April 1986, and successfully recovered a year later. Satellite-tracked beacons have been deployed on ice floes and on drifting buoys. (*Contact: H. Melling.*) Several types of numerical models of the response of currents to atmospheric forcing have also been developed. Although highly simplified, they have provided some interesting results. For example, ice cover shields the underlying water from the effects of wind drag, so that it was expected that wintertime currents would be unrelated to weather systems. However,the ice does transmit the barometric pressure, permitting the moving pressure gradients associated with weather systems to drive surprisingly rapid currents. The model currents are highly sensitive to even gentle topographic relief, breaking down into complex small scale patterns when not being forced directly by a large-scale weather

system. (*Contact: W.P. Budgell.*)

As part of the Northern Oil and Gas Activity Program, another project in the Beaufort Sea is concentrating on the behaviour and fate of natural hydrocarbons in the expectation that the results will also apply to hydrocarbons resulting from industrial development. A team drawn from Ocean Physics and Ocean Chemistry, with help from the National Hydrology Research Centre, plans to work from the continental shelf edge into the shallowest areas, where sediments are particularly mobile. Although the main field work will take place in 1987, a pilot cruise was conducted in 1986 aboard a chartered vessel the MV ARCTIC IVIK. In addition to testing techniques and equipment, the data obtained will provide comparison and reference for the more extensive surveys planned for 1987. (*Contact: R.W. Macdonald.*)

Large Scale Circulation and Climate

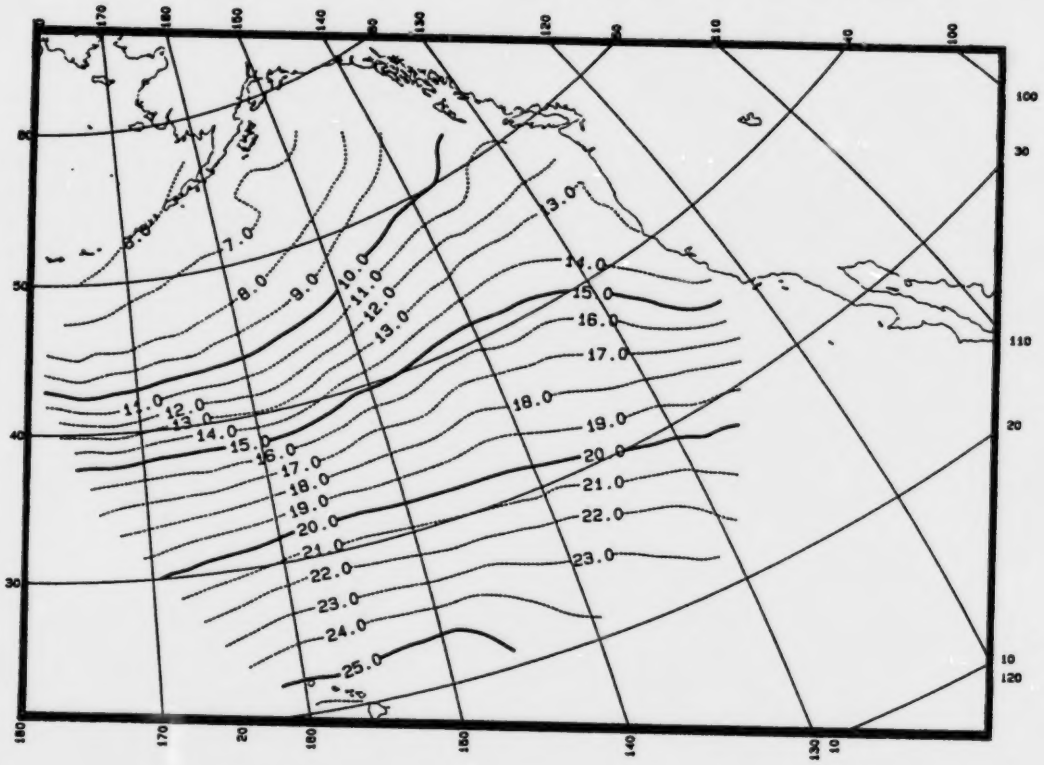
Water masses over the Canadian continental shelves consist of offshore ocean water slightly diluted by land runoff and ice melt. Changes offshore affect conditions in coastal waters and often cause economic impacts. For example, salmon spend at least half their lives in the open ocean and the oceans play a major part in controlling the weather patterns which make up climate, and in controlling the increase of atmospheric concentrations of "climate gases". Ocean studies have been identified internationally as a major component of the World Climate Research Program.

The main source of documentation of recent ocean climate variability in the Northeast Pacific is the time series of observations maintained at Ocean Weather Station P (50N°145°W). Between 1956 and 1981 observations were made by patrolling weather ships at Station P and along Line P leading to the mouth of Juan de Fuca Strait. Since 1981 observations have been made several times a year by special research cruises. Sampling has been extended to include Line R, between Station P and Cape St. James. Four cruises were made in 1986. A statistical analysis of the data obtained from Line P showed that the annual cycle in the central part of the Gulf of Alaska is mainly due to temperature fluctuations, while that over the continental shelf was mainly associated with salinity changes. (*Contact: S. Tabata.*)

Fallout from atmospheric tests of hydrogen bombs tagged the ocean's surface with an increased amount of tritium, which has provided a method of tracing the large-scale motion of ocean waters. An analysis of tritium observations at Station P between 500m and 1500m depth showed that they could not be explained in terms of mixing, and that advection by large scale currents was the most probable explanation. (*Contact: A.E. Gargett.*)

Data transmitted in real time over the IGOSS (Integrated Global Ocean Station System) network are being used to prepare widely distributed monthly maps of mixed layer and 100m depth temperatures in the North Pacific in a joint project with

MEDS. The observations, mostly coming from voluntary vessels deploying XBTs (expendable temperature profiling probes), are dense enough to permit a general assessment of the ocean climate situation and significant deviations from the normal, as represented by climatological averages. (*Contact: M. Miyake.*)



Mean mixed layer temperature in the northeast Pacific for 1986.

Estimates of the poleward heat transport of the North Pacific vary by an amount equal to the better known North Atlantic heat transport, or about 20% of the total estimated heat loss of the Northern Hemisphere. One area of uncertainty has been the heat transport associated with the intense eddy motion in the Kuroshio extension region. A recent analysis of XBT data suggests that these transports are not large enough to account for the discrepancies. (*Contact: A.F. Bennett.*)

Experiments on the long term effect of atmospheric changes on the global climate require numerical (computer) models which accurately represent all the important processes. Many models of large-scale ocean circulation have been constructed, but all require severe simplification of important ocean processes. Use of the world's largest and fastest computers permits sufficient resolution to represent the oceanic

equivalent of weather, but this can only be achieved for a reduced ocean basin and with a limited approximation to the ocean's vertical structure. Very long and costly computer runs are required before such models reach an internal equilibrium independent of the initially-imposed conditions. There is consequently great interest in the development of better approximations of the effects of eddies and small scale phenomena, and the research strategy at IOS has concentrated on this area.

The effect of small-scale processes such as turbulence and breaking internal waves on the vertical transfers of heat and momentum has been one topic of study. Analyses of observational data suggest that vertical diffusivity should depend on the stability of the water column rather than on the constant value normally used. (*Contact: A.E. Gargett.*) Numerical experiments have shown that internal wave motions actually act to increase stability, offsetting the effect of the turbulence induced by their breaking. (*Contact: G. Holloway.*) Another area of work has been the examination of mesoscale eddies, the "weather" of the ocean. A study of the interaction between random bottom topography and meandering currents uncovered an effect that would tend to cause currents along the continental margins which, in the northern hemisphere, flow keeping the continent to the right persisting against moderated opposing winds. (*Contact: G. Holloway.*)

Drifting buoys and mid-depth floats have been suggested as observation tools for studies of eddy diffusivities but the numbers available are usually insufficient to provide good statistical reliability. Consequently, results are difficult to interpret in large scale models. Theoretical work on this problem provided guidance on the confidence achievable with particular numbers of floats. (*Contact: A.F. Bennett.*) With some assumptions regarding the vertical structure of the current field, observations of sea surface slopes made with satellite altimeters can be used to map the horizontal eddy diffusivity. In some regions the values agree well with more conventional estimates but poor agreement in others suggests areas for further investigation. (*Contact: G. Holloway.*)

Simpler numerical models can be used to make short range predictions on the basis of recently obtained data, or to prepare an optimal description of the ocean's behaviour from data obtained over a long period of time. However, special techniques are required to permit the model to accept data which may not agree with its own predictive values. These data assimilation techniques are one area of activity in the Ocean Physics Division. Their use in tidal models has been explored recently. (*Contact: W.P. Budgell.*) Two general methods are being compared to assess the effectiveness of the XBT sampling being obtained in the TOGA (Tropical Ocean/ Global Atmosphere) experiment for detecting and measuring the particular type of equatorial current patterns expected in connection with El Nino events. One of these methods involves a retroactive determination of model parameters based on all the data collected to a given time, while the other uses a Kalman smoothing technique to reduce the "shock" effect of the introduction of new data values. (*Contact: A.F. Bennett, W.P. Budgell.*)

To investigate the dispersal of material originating from the hydrothermal vent fields on Endeavour Ridge, an array of moorings carrying current meters, sediment traps and recording transmissometers was installed around the vents in collaboration

with Oregon State University. Accelerated corrosion of stainless steel fittings, presumably due to the hydrothermal vent fluid, resulted in a much reduced mooring life. Data retrieved from the moorings closest to the vents indicated both tidal and near-initial components of the currents. The latter are probably excited by storm winds. The plume emanating from the vents was mapped using a towed CTD and transmissometer. (*Contact: R.E. Thomson.*)

The processes which control the exchange over the sills of British Columbia fjords also control the exchange between the Atlantic Ocean and the Mediterranean Sea through the Strait of Gibraltar. U.S. funding permitted participation in a project to study these exchanges providing an opportunity to test conclusions of exchange theories on a larger scale than is possible in local waters. A very successful field program was carried out from a U.S. vessel, involving moorings, a water property survey and the IOS acoustic doppler current meter. (*Contact: D.M. Farmer.*)

Upper Layer Processes

Ocean circulation is driven by forces exerted on its surface and by the exchange of heat and water through the surface. The processes involved must be described to predict the ocean's response to changing atmospheric conditions on all scales, from weather to climate. The motion of pack ice is partly controlled by its interaction with the ocean's upper layer. Ocean waves affect the safety of navigation and the survival of coastal and offshore developments.

U.S. funding permitted a team from IOS and the University of Victoria to participate in FASINEX (Frontal Air-Sea Interaction Experiment), in the Atlantic south of Bermuda. The behaviour of the clouds of bubbles generated by breaking waves was observed with acoustic and video techniques. This should eventually permit improved understanding of the role of wave breaking in the transfer of energy from the wave field to upper layer currents and provide some estimates of the importance of the bubbles in the transfer of gasses such as oxygen and carbon dioxide between the atmosphere and the ocean. (*Contact: D.M. Farmer.*)

Improved ice-motion forecasting requires improved understanding of the drag between the ice and the water underneath. Two processes are involved: frictional drag on the underside of the ice flows and form drag on the keels of pressure ridges. The latter is potentially the more important and is certainly less understood. A project on this topic is being carried out with sponsorship of PERD. A successful field expedition in 1985 provided observations indicating the types of processes taking place and has since permitted the construction of a laboratory model experiment to quantify the importance of various effects. (*Contact: D.R. Topham.*)

The temperature of melting and freezing depends on pressure so that water which is above the melting point at a few meters depth will freeze when brought closer to the

surface. This process acts to smooth out the underside of sea ice. (*Contact: E.L. Lewis.*)

Forecast Development

Tidal predictions have become an accepted tool for navigation and coastal development. Estimates of the probability and potential magnitudes of storm surges and tsunamis are essential for emergency planning. Effective coastal weather and wave forecasts are important to safe navigation and cost-effective exploitation of marine resources.

The computer programs developed at IOS for the analysis of tidal observations and the prediction of tides are very widely used. They have been distributed to 103 agencies in 21 countries around the world. (*Contact: M.G. Foreman.*) A package for automating the grid development for numerical tidal current models was completed and has already received significant interest on the part of outside agencies. (*Contact: R.F. Henry.*) The numerical tidal models developed for the Georgia Strait/Strait of Juan de Fuca/Puget Sound system are widely recognized as among the most successful available. A major effort to complete documentation for these models was initiated in the report period. (*Contact: T.S. Murty.*) In addition to providing tidal height and current predictions they can also be used to model the behaviour of storm tides and tsunamis. A comprehensive review of potential tsunami magnitudes for the entire British Columbia coast was begun under contract. (*Contact: T.S. Murty.*)

A program to improve weather and sea-state forecasting on the Pacific coast is being conducted jointly with Department of Environment and Ministry of Transport. One element of the program is the improvement of observational systems. A contract was awarded for the construction of large offshore meteorological buoys to be maintained at three locations. In the interim, a single buoy borrowed from the U.S. was moored at one of the sites in August 1986. Wave data are being provided in real time from a network of six buoys in coastal waters in co-operation with MEDS. Research conducted under contract showed that measurements of the winds within a few hundred kilometers of the coast are required to accurately predict severe waves. The resulting interest in more effective wind observing methods stimulated the development of a device suitable for use on inexpensive drifting buoys which infers wind speed from the characteristics of ambient underwater sound. Another project conducted by a research company investigated the effect of interactions between the wave field and tidal currents. The tidal currents in many areas of the open coast are strong enough to significantly increase wave steepness, and must be considered in predicting hazards to both navigation and offshore structures. (*Contact: J.F. Garrett.*)

Instrumentation and Observational Techniques

Understanding of ocean processes and phenomena is hampered by the difficulty of observing them. Water is opaque to light. Many important properties can only be detected by sensitive chemical analyses. Observations are expensive, particularly those requiring the use of dedicated research vessels. The accuracy and reliability of conventional instruments and analytical techniques needs to be refined or simply better understood. Increasing the number of parameters which can be automatically recorded would increase the effectiveness of ship use. Remote sensing techniques can provide new insight through new ways of looking at phenomena and can increase efficiency by extending the range of data gathering from a single platform.

A sensor to measure dissolved oxygen using fiber optics techniques has been developed under contract with a local company. In one of the successful tests a recording of dissolved oxygen fluctuations was obtained from a mooring also containing current meters. (*Contact: R.E. Thomson*)

Improvements in processing techniques have stimulated interest in underwater acoustics. Much information can be obtained from naturally generated noise in the sea. Noise levels in certain frequency bands are related to wind speed, while in others they are due to rainfall. Techniques for using both of these are currently under development in joint projects between the Ocean Physics Division and private companies. In ice covered areas ambient noise contains information about the condition of the ice. A simple multiband recorder placed under the ice in 1986 revealed that in winter the ice noise has a characteristic diurnal cycle, which diminishes as break-up approaches. Further investigation is planned in a project sponsored by PERD. (*Contact: R.E. Thomson*)

Other techniques involve the generation of sound and analysis of the signal received from after reflection from, or transmission through, scatters in the water. One such system uses transmitted sound pulses to measure the rate at which small inhomogeneities are carried between the transmitter and receiver, thus measuring the average current speed. This has been successfully demonstrated in a 600m wide tidal channel. (*Contact: D.M. Farmer.*)

Satellite images of ocean colour have found wide use as indicators of biological productivity and sediment load, but the accuracy of quantitative interpretations of these images is still not satisfactory under many conditions. The prototype of an advanced instrument with much higher colour resolution was completed earlier by a contractor, and has been undergoing testing and evaluation. Called the Fluorescence Line Imager or FLI because of its ability to distinguish the fluorescence of phytoplankton chlorophyll from background broadband light, its next use will be to map plankton distribution in Barkley Sound to determine whether ship-based samples properly represent the important features. (*Contact: J.F.R. Gower.*)

Ocean Chemistry

Activities of Ocean Chemistry during 1986/87 involved both applied and targetted basic research. The program emphasized climate research, including the capacity of the ocean to absorb CO_2 and other climatic gases, and pollution-related research.

Targetted basic research was focused on the oceanic modulation of the atmospheric burden of carbon dioxide (CO_2) and other "greenhouse" gases. Two areas received particular attention: the oceanic capacity to absorb CO_2 and other greenhouse gases, and the secular increase of CO_2 in both the atmosphere and the ocean. Related study was also conducted on the biogeochemical fluxes of the ocean to quantify the CO_2 sequestered as detrital carbon as a result of marine biological processes, often described as the "biological pump", moving carbon from the ocean's surface to the abyss. A chemical monitoring strategy was adopted in order to understand the variability of carbon cycles and other chemical parameters affecting the climatic system in the ocean. Both ships-of-opportunity, using trans-Pacific carriers, and dedicated research ships were used. One significant finding in this study period was the decrease in both nutrients and partial pressure of CO_2 in equatorial Pacific waters during the El Nino of late 1986.

Applied research was conducted in the areas of coastal pollution and acid rain. The pollution research addressed the dumping of mine tailings, exploration for oil and gas in the southern Beaufort Sea, dredged spoils and contaminated sediment, and contamination of shellfish, finfish and other marine organisms. To study the pathways and fate of natural organics and metals, ocean enclosure experiments were conducted in cooperation with visiting scientists funded by the Japanese Society for the Promotion of Science. Similar experiments into the pathways and fate of oil and oil dispersant, conducted at IOS and at the Third Oceanographic Institute at Xiamen, P.R.C., were funded by the Canadian International Development Research Centre (IDRC) and the Chinese State Science and Technology Commission.

The Beaufort Sea chemical oceanography project was supported by the Office of Energy Research & Development (OERD) and the Northern Oil and Gas Action Program (NOGAP). This project examined the baseline levels of hydrocarbons, sediment-oil interaction, chemical oceanography and seasonal changes in sea water chemistry and production. During 1986-87 time-series data collection commenced on ice and in open water.

A modest start to an acid rain program was made possible through cooperation with Atmospheric Environment Service (AES) of Environment Canada. A laboratory, equipped with an ion chromatograph and shipboard rain and aerosol samplers, was established. Preliminary results indicated low pH levels (≤4.5) in precipitation over the Strait of Georgia adjacent to B.C.'s lower mainland, possibly due to emission from the cities of Vancouver, Seattle and Tacoma. This may signal an emergent environmental problem requiring joint study with other DFO branches.

Centre for Ocean Climate Chemistry

CO_2 and Other Climatic Gases

The Centre for Ocean Climate Chemistry at IOS has been designated as a Centre of Disciplinary Expertise (CODE) for targetted basic research into the oceanic modulation of atmospheric CO_2 burden and other greenhouse gases. These gases, natural and other, have cumulatively emerged as one of the most significant factors affecting the global climate system. An international effort must be mounted to address the lack of long-term oceanic time-series data necessary for understanding the chemical climate system of the ocean. The Centre has been playing a major role in international forums such as the Scientific Committee on Oceanic Research (SCOR) Working Group-75 on Oceanic CO_2 Methodology and the CO_2 Panel of the Committee on Climate Change and the Ocean (CCCO).

An atmospheric CO_2 monitoring program was conducted jointly with AES as a part of the World Meteorological Organization's background monitoring network. The Centre at IOS served as the national analytical facility to assay the CO_2 contents in air samples from Alert, Sable Island and Cape St. James for seasonal changes and secular rise of CO_2. This laboratory, with a special cathetometer for ultra-precise and accurate measurements of pressure/volume/temperature-relations of gases with temperature controlled to ±0.02 °C, is one of only two such facilities in the world. In the laboratory emphasis was placed on developing quality standards for atmospheric and oceanic CO_2 long-term monitoring. Comparisons, such as the GMCC (Global Monitoring for Climatic Change) calibration exercise, carried out under the auspices of the National Oceanic and Atmospheric Administration (NOAA), the National Bureau of Science (NBS) and the World Meteorological Organization (WMO), involving laboratories in Canada, Australia, New Zealand and U.S., were undertaken. Results showed all labs to be compatible relative to the Scripps Institution of Oceanography WMO-85 scale.

Oceanic CO_2 monitoring during 1986-87 consisted of sampling from the MV LILLOOET, a container ship running between Brisbane in Australia, Noumea in New Caledonia and Richmond, B.C. and quarterly cruises to Ocean Station P (50°N 145°W) using IOS ships. Chemical measurements included partial pressure of CO_2 in both the atmosphere and the ocean, total CO_2, nutrients and chlorophyll-a. Temperature and salinity measurements were also taken. Intense surveillance detected the effects of the late 1986 El Nino on the chemical climatic system in the central equatorial Pacific Ocean. The partial pressure difference of CO_2 between the atmosphere and the ocean dropped to almost one-third normal value (100 ppm). The nutrient peak and usual temperature minimum at the equator, indicative of upwelling of CO_2-rich and nutrient-packed deep water, disappeared. The nutrients in the surface waters north of the equator, to 45°N, also were relatively low.

Modelling work centred on the construction of a one-dimensional model, based on time-series observations, describing the CO_2, nutrients and detrital carbon pro-

cesses affecting the carbon/CO_2 transfer at Ocean Station P. (*Contact: C.S. Wong.*)

Pollution

Enclosure Experiments

Cooperative work using special enclosure facilities was conducted at Patricia Bay in Canada and at Xiamen Bay in China. The project, carried out April 21 to May 16, with four IOS and four U.B.C. scientists working with colleagues from the Third Oceanographic Institute at Xiamen, the Environmental Protection Institute at Dairen and the Shandong College of Oceanology was funded by IDRC. The study examined the dispersion of very heavy Chinese crude oil from the Shengli oil field in Shandong Province and a dispersant produced in Shanghai. IDRC also funded the participation of four Chinese scientists in an experiment at IOS late in the year involving the bacterial action on a dispersed heavy crude oil and metal leaching from such a mixture to sea water.

A joint China/Canada research program, supported by IDRC (Canada) and NBO (China), studying the effects and fate of marine pollutants in sea water near Xiamen, China.

An enclosure experiment at IOS to study the vertical flux of natural hydrocarbons and metal behaviour of lead, cadmium, copper and zinc in sea water was supported by the Japanese Society for the Promotion of Science and involved the participation of five scientists from Nagoya University, University of Tokyo, Japanese Geological Survey and Aoyamagaku University from July 10 to August 10. (*Contact: C.S. Wong.*)

Hydrocarbons

Both NOGAP and IOS resources contributed to the Beaufort Sea pathways and fate study. Laboratory work focused on procedures for the analysis of polycyclic aromatic hydrocarbons (PAHs) and other organics in sea water and sediment trap samples. (*Contact: W.J. Cretney.*)

Metal Binding Proteins

An unsolicited proposal from CBR International led to a major effort to examine the metal-binding proteins in the oyster (*Crassostrea gigas*). Laboratory exposure experiments were conducted showing that metallothionein was not induced by exposure of oysters and mussels to 40 μg Cd L^{-1} and that metallothionein was not the only main metal-binding protein induced in organisms exposed to natural sea water or to 50 μg Cd L^{-1} solution. Metals bound in the cell membrane of oysters in coastal waters of Vancouver Island were at a higher level than those from laboratory exposure experiments. Copper, a legacy from the abandoned smelter at Osborne Bay, was found to be the contaminant metal in oysters from the Crofton area. The study developed the Molecular Indices of Metal Stress, with potential application to environmental monitoring. Further work, using invertebrates and salmonids would be desirable. (*Contact: J.A.J. Thompson.*)

Ocean Flux

The Ocean Chemistry Division has been conducting time-series studies of the ocean flux of carbon, phosphate, nitrate and silicate in the northeast Pacific Ocean. The behaviour of the oceanic biogeochemical cycle has been studied since 1982 using Ocean Station P, one of the few sediment trap flux monitoring stations. Three types of measurements were carried out during the study period. Primary productivity was determined using a metal-free C-14 tracer technique at a coastal station (P-3, 48.5°N 126.5°W) and at Station P by measuring the carbon uptake in incubated light and dark bottles suspended from a free-floating array at 10 metre intervals to a

depth of 100 m. Fluxes in the surface and intermediate waters (to 1000 metres) were measured by using a string of sediment traps, 100 m apart, set adrift for two-to-four days and located by a satellite-positioned ARGOS buoy. Deep-water fluxes of materials were studied using moored, automated sequential sediment traps. Samples of detritus were collected biweekly at 1000m and 3800m at Ocean Station P and 500m at Station P3 for periods up to six months. The sedimented materials could be used to assess surface productivity on the basis of a relationship between the surface production and fluxes at depth at the monitoring stations, so that the timing of plankton blooms could be detected from the time-series data. (*Contact: C.S. Wong.*)

Acid Rain

As a contribution to the Long-Range Transport of Atmospheric Pollutants Program and the up-coming Global Tropospheric Chemistry Program, an acid rain study was conducted with AES. Rain samples were collected during cruises in the Strait of Georgia and B.C. fjords and offshore along Line P. High chloride and sulfate were found in open-ocean precipitation and in precipitation from coastal inlets subjected to onshore winds direct from the Pacific. Nitrate was high in rain samples over the coastal waters near the Lower Mainland, possibly indicative of the influence of urban and industrial input. Samples collected in the Strait of Georgia had pH values of less than 4.5, compared to values of 5.0 to 5.5 for both remote inlets and offshore samples. Similarly low values were observed by other investigators in lakes on southern Vancouver Island and on the lower mainland. These low pHs could be signals of an acid rain problem on the Pacific coast, possibly due to emissions from the urban/industrial areas of Vancouver, Seattle and Tacoma. (*Contact: C.S. Wong and G. A. McBean.*)

Beaufort Sea Oceanography (NOGAP)

NOGAP (Northern Oil and Gas Action Program), funded by the Department of Indian and Northern Affairs, involves two territorial governments and seven federal departments. The goal of the program is to prepare government for major hydrocarbon development north of 60°. A sub-project of NOGAP, Beaufort Sea Oceanography, commenced at IOS in April 1986. Startup was preceded by several months of planning which progressed from broad objectives (the study of hydrocarbons and primary productivity) to a detailed interdisciplinary plan formulated in hypotheses. During the first six months the team and equipment were assembled, the plan revised and a late summer Beaufort Sea cruise on the ARCTIC IVIK organized. The latter half of the year was spent preparing equipment and logistics for the massive field program scheduled for spring 1987 and field testing the equipment and approaches to be used.

Hydrocarbons

To predict the impact of anthropogenic hydrocarbons on the Beaufort Shelf requires an understanding of the geochemistry of hydrocarbon in a shallow arctic estuary. Researchers can take advantage of natural analogues; the Mackenzie River, peat from coastal erosion, air masses from Europe and plankton are all hydrocarbon sources which are dynamically balanced by microbial degradation and sedimentation (sinks). The IOS plan is to measure the magnitude and composition of hydrocarbon for each of the major sources and to identify the sinks.

Hydrocarbons are difficult to measure in nature due to ultra-low concentrations and the possibility of contamination during sampling. The problem of collecting a single representative sample is offset by the rich spectral information available in a hydrocarbon determination run by Gas-Chromatography Mass-Spectroscopy (GCMS). Representative samples of all the important geochemical pools (Mackenzie River, zooplankton, atmosphere, etc.) and water and sediment types over the Beaufort Shelf will be collected. Chemometric modelling (mainly statistical approaches) will be used to unravel the hydrocarbon composition of the various pools by source. A hydrocarbon budget for the shelf will be established to check the model.

Hydrocarbon geochemistry (phase and composition) requires a variety of sampling approaches. The ARCTIC IVIK cruise provided a rugged test for equipment and yielded representative samples with which lab methods were developed. New equipment and procedures were then further tested and compared in the Fraser River estuary before shipping north.

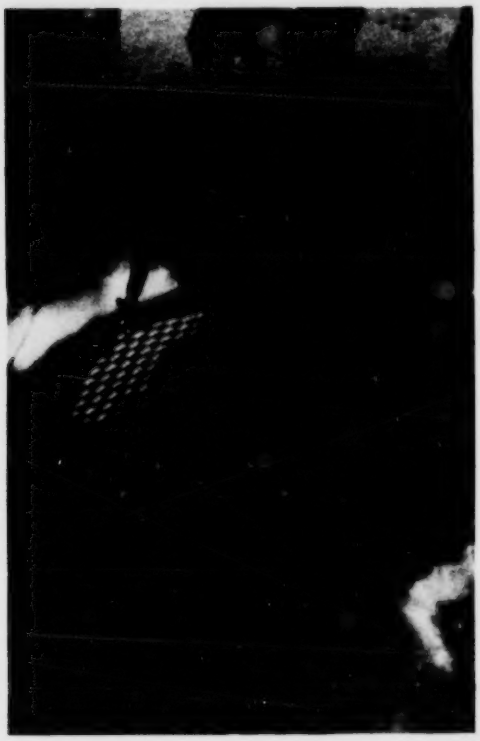
Productivity

Circumstantial evidence points to spring breakup as the critical period for primary food production on the inner Beaufort Shelf. Unfortunately, the difficulty of sampling at that time has resulted in virtually no direct measurements of the rate of production as it relates to light regime and nutrient supply. To redress this two independent strategies for making relevant measurements were planned; a time series spanning breakup on a transect extending across the shelf and the use of sequential traps to catch the fallout record during the critical period. Much of the first six months was spent in buying and building components, designing and constructing the moorings and preparing all logistics to support field work on the ice.

The ARCTIC IVIK cruise in September 1986 allowed the collection of a preliminary data set relevant to the measurements to be made during the 1987 transect study. Further, data collected will enable inter-annual comparisons with future measurements. Bongo sediment traps and current meters were moored on the shelf and

numerous details critical to the smooth execution of field work in the upcoming year were tested. These included quasi real-time satellite imagery on the ship, CTTD techniques, bottom mooring of Kenny traps and transmissometers.

After the ARCTIC IVIK cruise a major effort was applied to preparing all equipment to go north by March 1987 to take advantage of the ice-road to Tuktoyaktuk. Logistics (accommodation, aircraft charter, personnel and lab schedules and analytical protocols) were organized and field work from a Tuktoyaktuk base commenced in late March 1987. (*Contact: R.W. Macdonald.*)



A sequential trap being lowered through a 1.1 metre diameter hole melted through two metres of ice off Cape Bathurst prior to ice breakup 1987.

Ocean Ecology

(see Biological Sciences)

Data Assessment

The major functions of this group, formerly known as Ocean Information Division, are facilitating access to scientific information and data and providing advice about the marine environmental effects of industrial development. The Division also is involved in co-ordinating planning activities within the regional Science sector and has been designated the first point of contact within Science for a number of clients including DFO habitat management staff.

During 1986/87, the Division completed several planning exercises and was involved, with regional headquarters staff, in developing a new planning cycle and the tools for displaying objectives, results and activities.

Climatology

The B.C. Shorestation Oceanographic Program continued to obtain daily surface (one-metre depth) seawater salinity and/or temperature measurements at 16 locations in 1986. Preliminary examination of the 1986 data suggested little variation in temperature or salinity values from the long-term means. The much lower-than-normal temperatures that characterized most of B.C. coastal surface waters during November/December 1985 were generally replaced by "normal" values by the end of January 1986.

The West Coast Data Inventory and Appraisal Program (WESCAP) - which was originated to provide access to Canadian west coast oceanographic data - made slow but steady progress in 1986. The inventory dealing with the chemistry of the Dixon Entrance-Hecate Strait-Queen Charlotte Sound area was completed. This information, as well as that dealing with physics coastwide except for the Strait of Georgia area, is now also available to users by means of a computerised interactive database. (*Contact: L.F. Giovando.*)

Environmental Advisory Services

For many years, DFO has been a partner in a government-wide thrust towards improving the safety and reducing the environmental impact of northern hydrocarbon operations. In the field of habitat protection, concerns about possible environmental effects have promoted research into cause-effect relationships and the basic processes of Arctic marine ecosystems. Research at IOS is aimed at improving the ability to forecast ice and water movement, and at understanding the physical, chemical and biological processes that might influence the fate and distribution of hydrocarbons spilled into the Beaufort Sea. During 1986/87, staff reviewed the documentation associated with applications for 13 northern well sites and provided oceanographic and hydrographic advice to government regulatory agencies. From an environmental perspective, the major DFO concern was the efficacy of the contingency measures proposed to reduce marine impacts in the event of an oil spill and with the contamination potential of oil-based drilling muds. (*Contact: R.C.H. Wilson, B.D. Smiley.*)

Hearings under the auspices of the Governments of Canada and British Columbia into the removal of the offshore hydrocarbon exploration moratorium for the waters north of Vancouver Island, i.e. Queen Charlotte Sound, Hecate Strait and Dixon Entrance, culminated in the recommendation that exploration could proceed under certain conditions. In 1986 DFO participated as an advisor in an inter-governmental review of the Panel's report. In response to two Panel recommendations, review of the adequacy of on-going hydrocarbon-related research in DFO is underway and plans have been made to accelerate research on surface currents in this area. (*Contact: R.C.H. Wilson.*)

DFO has a responsibility under the Ocean Dumping Control Act (ODCA) for research into environmental questions raised by administration of the Act. The Division continued to support the Pacific and Yukon Regional Ocean Dumping Advisory Committee (RODAC Pacific). More than 50 applications for ocean dumping on the B.C. coast were assessed. A review of historical environmental data from the dumpsite off Point Grey, the most frequently used ocean dump site on the Canadian west coast, revealed several difficulties in both the analysis and interpretation of spatial and temporal trends in the parameters established for long term monitoring. The difficulties in evaluating trends were related to changes over time in the sampling schemes and in analytical techniques. Several recommendations were made to overcome the problems in future.

In some cases, the chemical analyses supporting an ODCA application for ocean disposal of dredged material indicate a low level of contamination. Considerable effort has been spent in the last decade to find ways of determining what proportions of contaminants in sediments are available and toxic to marine life. An evaluation of sediment toxicity tests that could potentially be incorporated into an ODCA testing protocol showed two that could readily be used to provide additional information - a lethal toxicity bioassay with the amphipod *Rhepoxinius abronius* and a bioaccumulation test with the clam *Macoma balthica.* (*Contact: L.F. Giovando.*)

Information Management

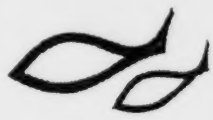
A computer-based directory, Oceanographic Data Information System, to all known oceanographic data in western Canadian Arctic and B.C. marine waters has been under development since 1981. ODIS offers a system to determine quickly and easily "who measured what, where, how and when", as far back in time as the last century. This geographically-referenced directory is intended for those involved in research planning, impact assessment, regulatory review, marine engineering, resource management, mariculture and related coastal zone activities.

Rapid interactive access is provided to ODIS through an applications database and associated search and display software running on a Microvax II computer. Off-site use requires only a VT-type or Tektronix terminal.

ODIS presently offers directories to Beaufort Sea and Northwest Passage data, including ocean currents, temperature, salinity, water levels, hydrocarbons, trace metals, nutrients, and marine and anadromous fishes; more than 12,000 stations can be searched, mapped and queried for dataset details. In addition, the directory contains an inventory of 18,000 stations with measurements of currents, temperature, salinity, water levels and waves activity for all coastal B.C. waters to 200 miles offshore, except for those east and south of Vancouver Island. ODIS also offers rapid summaries of current meter data collected by scientists at IOS and by the offshore oil and gas industry.

The contents of ODIS also exist as a set of catalogues produced by IOS as part of the Arctic and West Coast Data Cataloguing and Appraisal programs (known as ADCAP and WESCAP). In several thousand pages of tables, maps, references and indices, these catalogues describe the availability, completeness and reliability of the historical oceanographic data. (*Contact: B.D. Smiley.*)

BIOLOGICAL SCIENCES BRANCH



Biological Sciences

Dramatic changes in the organization of the Department of Fisheries and Oceans in the past year have focussed attention on scientific accomplishments as well as the future direction of the department's science. The projects described in this report indicate significant progress in the understanding of the fisheries resource on the Pacific coast. Databases have been established to facilitate management strategies which allow longer-term predictions and introduce more stability into fisheries management. A number of the projects described here are designed to improve these databases and models and subsequently the ability to predict allowable catches. To formalize the process for stock assessment review and provide a vehicle for discussion of stock assessment information and management recommendations, the Pacific Stock Assessment Review Committee (PSARC) has been created.

Research in Biological Sciences ranges from development of new theoretical models to the description of new species. Staff are active in almost all areas of fisheries science and have become involved in a myriad of client meetings. In spite of these demands, the contribution to the primary scientific literature has tripled over the last seven years.

Biological Sciences Branch is extensively involved in fish culture research with almost 25% of staff working on aquaculture or salmon enhancement research. A number of exciting contributions have been made to the development of aquaculture both in British Columbia and internationally. The next few years will see the establishment of a new aquaculture biotechnology program, expansion of disease research effort, the continuation of nutrition research and the development of methods for culturing new species.

Several years ago studies were initiated to examine the way in which ocean variability affects recruitment. This emphasis on research into the factors that control marine survival continues with exciting results. Theories have been developed to explain fluctuations in herring, sablefish and crab abundance. The new Marine Survival of Salmon (MASS) Program is attempting to identify the factors that affect the abundance of salmon upon entering the ocean environment. Through this study scientists hope to identify causes of marine mortality of salmon - perhaps one of the most significant science challenges on the Pacific coast.

Readers of this report may also be interested in the preliminary results of the programs to study the carrying capacity of the Fraser River and fish/forestry interactions.

The changes and uncertainties inherent in a major reorganization have not affected the ongoing commitment of those dedicated to fisheries science. The next ten years will be a most important and exciting time for fisheries research. As demand for quality seafood increases, aquaculture will continue to gain in importance. It appears that the "non salmon" resources, such as herring, shellfish and groundfish, will rival salmon in terms

of landed value thus meriting increased research effort. New technology and improved international co-operation will lead to discoveries of some of the basic principles that regulate fish populations. We can all take advantage of the new science organization to make some of the most significant discoveries in the history of Fisheries and Oceans science. *(Contact: R.J. Beamish.)*

Salmon and International

This Section has responsibility for providing the stock assessment and biological advice necessary to manage and conserve Canada's Pacific salmon resource, which is composed of several thousand discrete stocks. Responsibility for research into the biology and behaviour of marine mammals also rests with the section.

Species Report

Research began into the biochemical genetic methods of stock identification for Yukon River chum and chinook salmon. The purpose was to identify salmon originating in either the Yukon Territory or Alaskan portion of the Yukon River drainage. The identification of country-of-origin of salmon caught in different fisheries within the river is important to Canada/United States negotiations regarding the Yukon River.

New techniques were developed and evaluated to estimate stock composition of sockeye catches in mixed-stock sockeye fisheries. These techniques involved the use of parasite, genetic and scale pattern "markers" that vary from stock to stock. Stock identification techniques are required to monitor compliance with the Canada/U.S. Pacific Salmon Treaty. They are also used to estimate sockeye escapements to stocks within large river systems like the Stikine, Taku and Nass.

Research into the developmental and juvenile biology of Pacific salmon proceeded on several fronts. Marking and sampling studies were initiated in 1986 to determine density, growth patterns, migration and residence of juvenile sockeye salmon that rear in groundwater side channels of the Stikine River. These salmon are atypical because they do not utilize nursery lakes like most sockeye populations and many migrate to sea within their first year of life. It was recently established that these "river-rearing" sockeye account for approximately half of the total sockeye production in the Stikine River. (*Contact: C. Wood.*)

Another project was designed to determine whether the variation in size of pink salmon between stocks has a genetic basis. Pink salmon from two northern and three southern British Columbia stocks were reared under the same conditions and

their body weight periodically examined. Pink salmon from the northern stocks grew faster than those from the south, perhaps partially compensating for their later time of natural fry emergence and earlier spawning. Biological differences in the life history of pink salmon spawning in even- and odd-numbered years were examined. Pink salmon spawn only in odd-numbered years in the Fraser River, and attempts to introduce an even-year run have been unsuccessful. Pink salmon normally mature at two years of age, and research was conducted to produce mature one year and three year old fish. This will then allow the genetic characters of the odd-year run to be used in an attempt to produce an even-year run, because the odd-year run has the genetic adaptations to exploit the Fraser River environment.

Finally, variations among stocks in characteristics such as embryo survival rates, hatching time and fry size were examined in coho, chinook and sockeye salmon. The work indicated that there is variation in the developmental characters examined, and that this variation is likely a result of adaptations to specific environments in the home river. This work may have application in enhancement or transplant initiatives. (*Contact: T. Beacham.*)

Research into factors affecting coho productivity and stream indexing methodologies is considered to be a high priority. To manage fisheries on coho stocks, fishery managers need to know population characteristics, such as the escapement level which will produce maximum sustained harvest and the exploitation rate associated with that escapement level. Habitat managers need to know the physical attributes of quality fish habitat and must be abe to quantify them. To answer some of the questions resulting from these needs three areas were selected for study: the Cowichan and Keogh River systems on Vancouver Island, and the Lachmach River system in north coastal British Columbia.

In 1986 a fence was constructed on Mesachie Creek in the Cowichan watershed, and adult coho were counted in the fall. Smolt trapping and tagging began in the spring of 1987 and will continue on an annual basis to determine the ocean distribution and survival rate of Cowichan coho. An extensive survey of rearing habitat was conducted in the fall and winter of 1986 to determine the spatial and temporal distribution and re-distribution of stream and lake rearing salmonids. (*Contact. B. Holtby.*)

In the Keogh River system, surveys were conducted to investigate the growth and abundance of juvenile coho in different freshwater environments (lakes, streams, main river habitats). Juvenile dispersal patterns were documented and adult fences were maintained on one key tributary to evaluate the role of adult spawning on the distribution of juveniles in headwater areas. (*Contact: J. Irvine.*)

A smolt trapping and tagging program was begun on the Lachmach River in the spring of 1987, and construction of a permanent adult/juvenile enumeration and trapping fence will be completed for the 1988 field season. A small lake on this system will permit an investigation of the importance of lake rearing for northern coho stocks. (*Contact: R. K. Kadowaki.*)

The stream indexing project is evaluating whether counts of adult salmon in particu-

lar reaches of a stream can be used as an accurate index of the escapement to that stream and whether escapements of different stocks in a region correlate with each other. The project will also pursue alternative escapement enumeration methodologies including novel fence designs.

In 1986 a stream indexing project was carried out by the University of British Columbia and supported by the Department. The project involved the examination of three wild stocks and a number of hatchery stocks on the east coast of Vancouver Island to determine whether similarities exist in ocean distribution, exploitation rates, survival rates and escapements in adjacent hatchery and wild coho stocks. The project will continue at least until the fall of 1988. Also in 1986, an in-stream indexing project was conducted at one of the fences in the joint study. Results were promising and the project will be expanded in 1987 to cover two additional streams. (*Contact: J. Irvine.*)

Work in the area of coho colonization began in 1985 in response to a need identified by DFO operations staff. Initially the work was conducted in a variety of east coast of Vancouver Island streams, but the emphasis in 1986 shifted to the Cowichan River system where coho productivity work was being conducted. Smolt production from Grant Lake, which had been stocked in the summer of 1985, was assessed in the spring of 1986. Approximately 20 percent of the fry released migrated as unusually large smolts. Only a few juveniles chose to remain in the lake for another year.

In addition to the experimental stocking of Grant Lake, two streams were stocked and assessed as part of a co-operative effort between the Salmonid Enhancement Program (SEP) and Fisheries Branch to determine the effectiveness of fry salvage and stocking as an enhancement technique. (*Contact: R. Bams.*)

Ocean Studies

Recently Canadian researchers have placed increasing emphasis on developing a better understanding of the marine phase of the salmon life cycle. It is particularly important to determine the reasons for, and magnitude of, marine mortality of juveniles to better predict the number of adults available for harvest and for spawning. The reason for the better than 90% mortality rate of Pacific salmon during their marine phase is not currently known, but many experts consider the initial few months after the juvenile salmon enter the ocean to be the most critical period. Variable mortality rates during this period may also account for much of the natural year-to-year variation in the number of returning adults. An intensive field sampling program was conducted in Masset Inlet from 1982 until 1985 to determine the abundance, residence times and sources and rates of mortality for juvenile salmon. The results of this project confirm that predation can be a major source of mortality during the early sea-life period. Total losses of pink and chum salmon were estimated to be 1.8 to 2.9 million in 1983 and 1.6 to 2.6 million in 1985. This represents a loss of at least 12% and 18% of all the young pinks and chums that entered Masset Inlet in 1983 and 1985 respectively. Immature (yearling) coho salmon were the most

important predators, consuming an estimated 1.3 to 2.0 million pink and chum in 1983 and 1.0 to 1.7 million in 1985, or approximately 2.4 and 1.8 times more than all other predators combined for these two years. The results of this project support the conclusion that mortality rates of juvenile salmon are high during the early sea life period. However, the observed mortality rates and year-to-year variations are not sufficient to account for the observed variations in the numbers of returning adult salmon. The data on coho predation provide the first documented evidence of significant negative interactions between the various species of salmon. *(Contact: B. Hargreaves.)*

A joint research project, Meteorological and Oceanographic Influences on Sockeye Tracks (MOIST), between DFO and UBC was initiated in 1984 to investigate the relationship between inter-annual variability of the ocean-atmosphere system and the migration routes and timing of adult sockeye salmon returning to spawn in the Fraser River.

Work completed in 1986 included analyses of commercial troll vessel data and ocean temperature, which led to the discovery that year-to-year variations in the migration route of sockeye around Vancouver Island are highly correlated with near-shore, sea-surface temperature data. A pre-season estimate of the percentage of the sockeye run that would return to the Fraser River via Johnstone Strait was made and subsequently proved to be quite accurate. This work has also generated a new hypothesis - that fresh water discharge from the Fraser River and sea surface temperature patterns offshore do not guide sockeye salmon in a direct manner, but reflect atmosphere-ocean conditions that affect the ocean distribution of sockeye prior to the homing migration and hence their migration routes.

The distribution of sockeye salmon in Queen Charlotte and Johnstone Straits was also determined by test fishing with commercial seine vessels.

Tracking of individual adult sockeye using ultrasonic tags also proved very successful in 1986. Sixteen fish were followed, with depth of these fish recorded for a total of 225 hours covering a distance of over 450 km. The results indicate that the average migration speed was about 2 km/hr and that daytime speeds tended to be somewhat higher than those at night. The average depth of the migration in 1986 was about 20 m. The sonic tracking data demonstrate that Adams River sockeye migrate deeper than Quesnel River sockeye. *(Contact: K. Groot.)*

In addition to the coastal work, Canada is also interested in determining the distribution of Canadian salmonids on the high seas and the extent to which they may be caught in ocean fisheries. There is particular interest in assessing to what extent steelhead trout, chinook and coho salmon originating in Canadian waters may be taken by the Japanese land-based fishery.

The High Seas Salmon Project was initiated in 1986, and involved the participation of a Canadian scientist aboard one of the Japanese research vessel high seas cruises fishing with both drift (gill) nets and long line gear. In addition, high seas drift net fishing was also conducted by the Fisheries Research Vessel W.E. RICKER. The Japanese vessel fished over an area from 42° to 47°N latitude and 166° to 175°E

longitude and the catch included coho, sockeye, pink, chum and chinook salmon, and steelhead trout. The adipose fin had been clipped on one coho salmon and 11 steelhead trout, indicating that North American salmonids are present in this fishing area. Many of the salmon captured by longline on this cruise were tagged and released, which should provide additional data on continent of origin of salmonids found in this area. (*Contact: R. LeBrasseur.*)

Sockeye Enhancement Assessment

As part of the lake fertilization research program conducted in 1986, it was shown that the anomalously low returns of sockeye salmon to the west coast of Vancouver Island during 1985 and 1986 were due to oceanic factors and not to freshwater events. In addition, effective and cheap hydroacoustic and trawl procedures were developed that can be used to assess sockeye salmon escapements in numerous coastal lakes. (*Contact: K. Hyatt.*)

Sport Fishery Research

Research projects were conducted to provide data on hooking mortality of sport-caught and released salmon, the contribution of hatchery coho to the sport fishery and an initial assessment of fish attracted to an artificial reef in Nanaimo Harbour.

The hooking mortality study involved coho salmon entering their second year in salt water. Referred to as "bluebacks", these coho are caught in large numbers during April and May and many small fish, with a fork length of between 35 and 40 cm, are released. The coho were caught with standard sport trolling tackle and held in tanks and net pens for 24 hours to assess short-term mortality.

Late summer coho, with fork lengths greater than 50 cm, were also studied. Caught in the Campbell River area, the fish were tagged and released either immediately or after being held in a net pen for at least six hours. Analysis of the data on coho hooking mortality will be completed in the winter of 1988.

To determine the contribution of hatchery coho to the Georgia Strait sport fishery, volunteer anglers and guides kept logs of their catches and recorded the numbers of fin-clipped coho. The data are now being analyzed to provide an estimate of the ratio of hatchery fish in approximately ten different areas within Georgia Strait.

Recently divers conducted line transects in and around the artificial reef built in Nanaimo Harbour in 1985 and which has attracted a substantial population of fish. The study indicated the concentration of rockfish and lingcod is much higher on the reef than in adjacent areas. (*Contact: T. Gjernes.*)

Coho salmon (blueback) is caught using standard sport trolling tackle as part of a hooking mortality study.

After the hook is removed and the fork length measured, the fish is held in a net pen or tank for 24 hours to assess short term mortality.

Salmon Stock Assessment

The Stock Assessment Program involved five main activity areas during the year: development of assessment information systems, evaluation of the production from B.C. salmon stocks, development of analytical models, monitoring the catch in coastal troll fisheries and the catch of chinook in the Johnstone Strait seine fishery, and provision of hydroacoustic services.

The program maintains three principle databases for salmon assessments: historical catch, spawning population sizes and coded-wire tag. The coded-wire tag database will be one of the most complex fisheries databases in existence. It will contain total hatchery production of salmonids throughout the Pacific coast of North America, all releases and recoveries of coded-wire tags, and sampling information associated with the release and recovery of tags in order that statistical confidence in this data can be assessed. A significant advancement to this database in 1986 was the incorporation of tag recoveries from salmon escapements. This database may now be used to determine exploitation rates and annual survival rates of tagged salmon stocks.

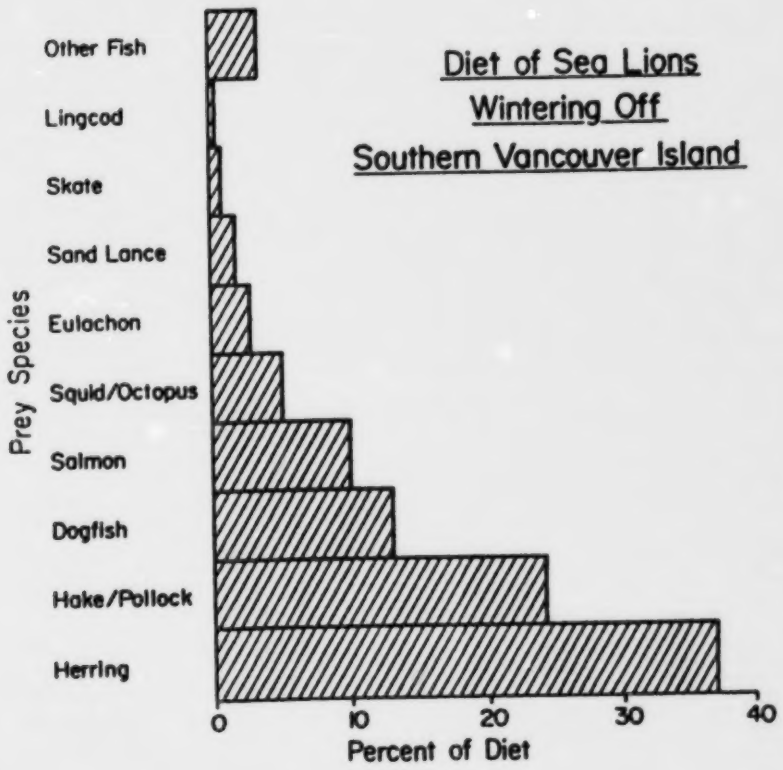
Several significant activities pertaining to the assessment of production from B.C. salmon stocks occurred during 1986/87. These included: i) evaluation of the contribution of Canadian hatchery chinook and coho salmon to Canadian and American fisheries, and the co-operative development with other DFO groups of an evaluation of the Salmonid Enhancement Program through 1985; ii) initiation of Fraser River sockeye and pink salmon stock assessment, a responsibility previously held by the International Pacific Salmon Fisheries Commission; iii) investigation of the utility of time-series forecasting (the technique which appears to be the most reliable one available compared to other standard methods) to predict the next year's abundance of salmon for a particular stock; and, iv) provision of advice to Canadian members of the Pacific Salmon Commission (PSC) and the International North Pacific Fisheries Commission (INPFC).

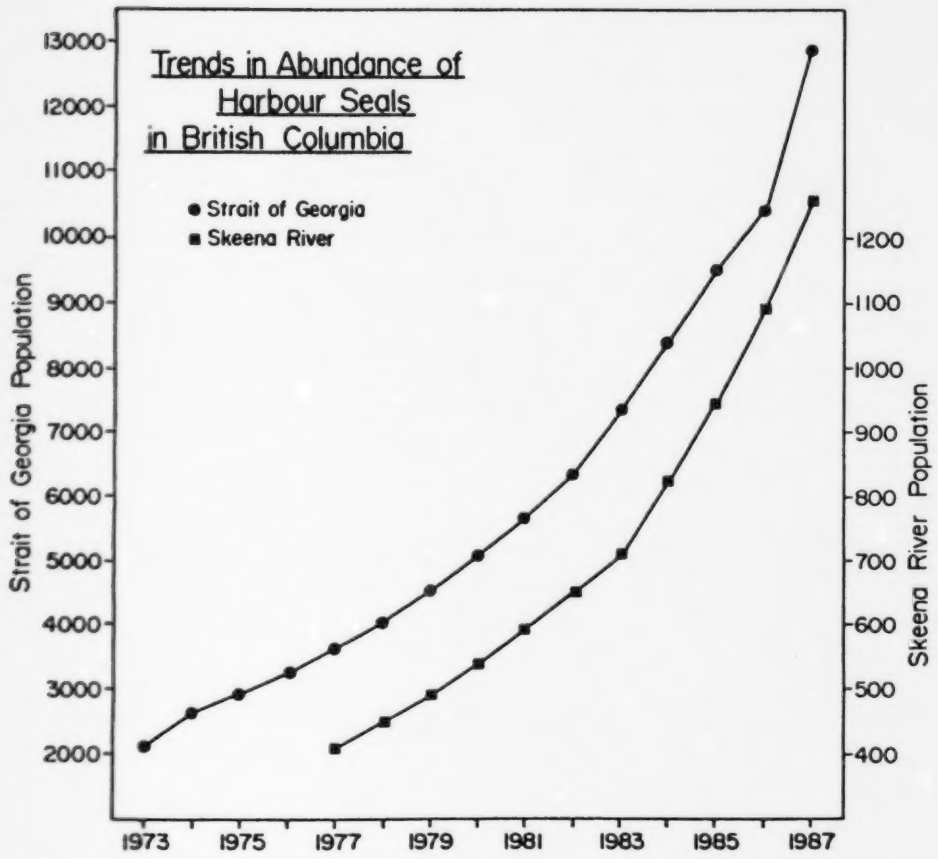
Two important programs involved monitoring the catch of chinook and coho salmon. The monitoring of catches in quota fisheries (established under the Canada/U.S. Salmon Treaty) required a specially-designed sampling program which would provide timely information. A program, based on observed fishing effort and catch per unit of effort, was successfully used in 1986 to manage the fisheries. Also in 1986, a pilot observer program was designed and conducted to estimate the total catch of chinook salmon in the Johnstone Strait seine fishery. The program proved to be highly successful as indicated by the close relationship of catch estimates of large chinook and sockeye to final sales records. The program further indicated that in 1986, approximately one small chinook (under 5 lb) was caught per large chinook but that only about one-sixth of the small chinooks caught were reported in records of sales. (*Contact: B. Riddell.*)

In 1986, the section assumed responsibility for the Branch's hydroacoustic services. A major portion of staff time was dedicated to establishing hydroacoustic capabilities on the FRV W.E. RICKER. (*Contact: R. Kieser.*)

Marine Mammals

Field work was completed on a four year study of the abundance and diet of Steller and California sea lions off southern Vancouver Island. These species are present in the region during late fall to early spring. Abundance was determined from aerial photographs taken at haulout sites. Steller sea lions have increased in number from about 700 in the early 1970s to stabilize at about 1,200 during the 1980s. California sea lions have increased from 500-1,000 in the late 1970s to 4,500 in 1984, although have since stabilized at about 3,000 individuals. These increases have resulted from changes in distribution of the wintering populations rather than from increases in the size of breeding stocks. Preliminary results from diet studies suggest that herring make up about 35% of the diet, while hake and pollock together comprise 25%, dogfish about 15% and salmon about 10%. Analyses continued on estimates of the impact of sea lions on commercial fisheries. (*Contact: M. Bigg.*)





Field work began on a study of the impact of harbour seals on the commercial fisheries off Vancouver Island. This project involves the collection of data on seasonal changes in number and diet of seals. Abundance is determined from aerial census and diet is established from an examination of scats and stomach contents. An aerial census undertaken in Georgia Strait indicated that the population continued to increase at about 12% per year, as it has done since 1973. The population between Victoria and Campbell River is estimated currently at about 9,900. The increase in number results from recovery following severe depletion through hunting for predator control and pelts prior to 1970. A larger program, involving analysis of historical data, the collection of new data and an aerial census, was also conducted to estimate abundance and trends coastwide. (*Contact: P. Olesiuk.*)

Records of the number of northern fur seals killed on St. Paul Island, Alaska, were used to describe the migration arrival schedules of each age and sex. The results indicated that males tended to arrive before females, and immature males and females arrive progressively earlier with age. A study, carried out jointly with the National Marine Mammal Laboratory in Seattle, examined the diet of northern fur seals along the west coast of North America. Stomach contents from 18,000 fur seals collected between California and Alaska were used to describe diet by month and region. Small schooling fish, such as anchovy and herring, comprised about 40% of the diet, and squid about 17%. Salmon made up about 6% of the diet.

Long-term studies continued on the general biology of killer whales in British Columbia. Photographs of recognizable individuals were used to accumulate data on abundance, movement patterns, vital statistics, diet and behavior. (*Contact: M. Bigg.*)

Fish Age Determination Unit

Over the last few decades, fisheries biologists have come to realize the importance of accurate fish ages and the consequences of relying on inaccurate age information. Reliable ages are essential to understanding the biology of fish, assessing the condition of economically important stocks and developing rational management strategies.

The research mandate of the Ageing Unit is to develop new ageing methods and improve on existing ones. This is done through developing and publishing ageing criteria, carrying out validation studies and establishing standards.

The Fish Age Determination Unit at the Pacific Biological Station provides ages to assist fishery managers. On the Pacific coast this means age determinations of more than fifty groundfish stocks, e.g. sablefish, hake, rockfish and flatfish, as well as herring and salmon species. During the fiscal year 1986/87, the Unit aged 14,500 groundfish; 40,000 herring and 11,100 salmon. The age determination process often involves examination of more than one structure by more than one reader.

Since its establishment in 1977, the Unit has become an international focus for fish ageing research. This is reflected in the number and diversity of consultations with other agencies and researchers during 1986/87. These included: within Canada, academic institutions and various federal and provincial government agencies; in the U.S., state and federal agencies; and overseas, a variety of fishery management agencies and researchers from U.S.S.R., Japan, New Zealand, Australia, Spain, China, Korea, Kuwait and Norway.

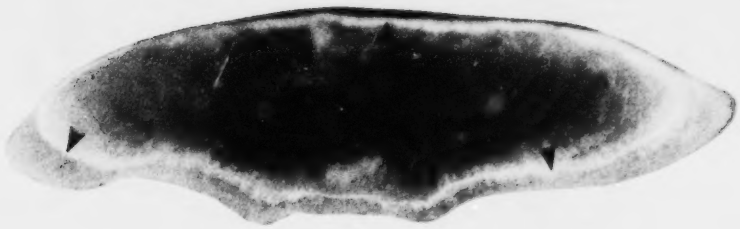
An ageing structure study of chinook salmon spawners led to the discovery of an ageing method using dorsal fin ray cross-sections which is more accurate than the conventional scale method. The study indicated that scales were not reliable indicators of age due to the resorption process which occurs as salmon begin their fresh-

water spawning migration. In many cases, these scales are "unageable". A processing technique and ageing criteria for the new method were developed over a three-year period providing the capability to accurately assess freshwater, ocean and total age. It has been recommended that this new method be used instead of, or in conjunction with, scale readings for age determinations of chinook salmon spawners.

Dorsal fin cross-section from a chinook salmon. Five annuli (winter zones) are indicated by arrows.

Traditionally, scales have been used to age herring. While comparison of scales versus an otolith cross-section technique concluded that scales adequately aged the bulk of stocks studied, it is believed that the otolith method more accurately estimates ages of older fish, i.e. more than seven years). Therefore, otolith samples were collected from stocks containing older fish, to complement scale ages. At this time, both methods require validation.

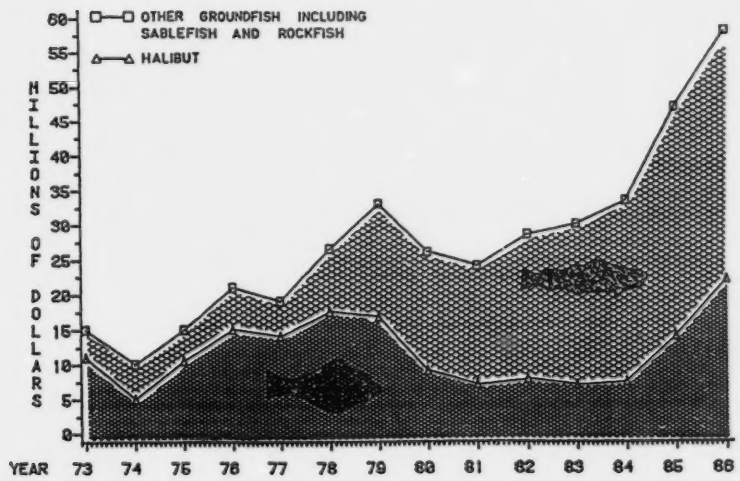
A preliminary study to determine validation of the burnt otolith cross-section technique for ageing rock sole was completed. Other on-going projects included sockeye salmon scale pattern analysis for stock identification, with 1,800 scales digitized in 1986/87; sockeye salmon spawner age structure comparison; a chinook salmon preferred scale study; a Pacific cod fin-ray study; sablefish age validation; completion of a salmon age structure field guide and development of standard procedures for measuring age determination precision. (*Contact: G.A. McFarlane.*)



Cross-section of a rock sole otolith. Arrows point to the oxytetracycline (OTC) mark. OTC is a chemical injected into tagged fish. It is deposited onto bones forming a mark which fluoresces under ultraviolet light.

Groundfish

Both the size and value of the groundfish fishery have increased dramatically in recent years. The value of these fisheries has almost tripled since Canada extended its fisheries jurisdiction in 1977 . However, some resources such as pollock, spiny dogfish and Strait of Georgia hake are still underutilized.



In 1977 the landed value of groundfish was approximately $20 million. In 1986 this had increased to approximately $70 million.

Groundfish research is designed to determine the maximum (or optimal) yield from each species, a process which involves four steps: identification of individual stocks within species; determination of annual and seasonal abundance and production; determination of biological properties such as growth, longevity, natural and fishing mortality rates, fecundity and life history; and, development of mathematical models incorporating these parameters which can simulate the response of a stock to fishing and non-fishing environmental factors. Studies recently initiated will develop more complex modelling, involving relationships between stocks of different species occupying the same fishing grounds.

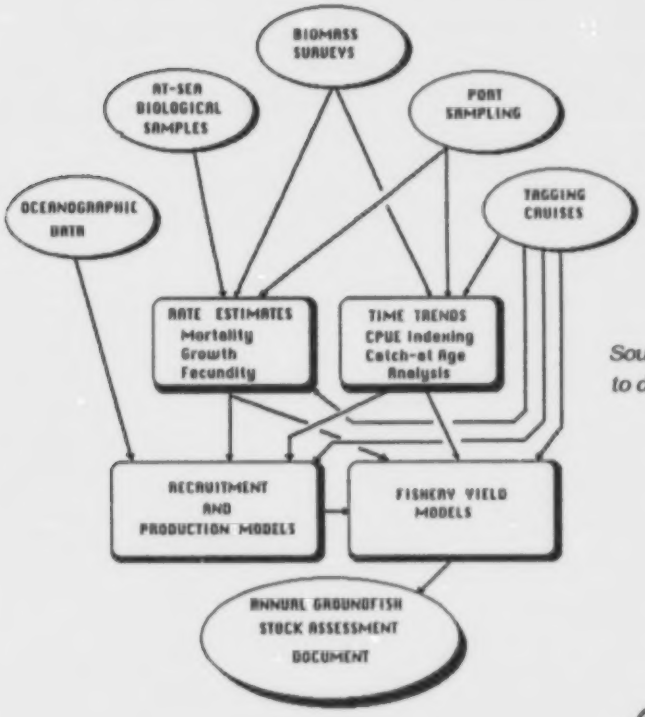
In particular, studies in 1986 focused on: methodology development of fishery-independent stock assessment; increased understanding of recruitment variation; examination of the biotic and abiotic factors which determine year-class success; and, incorporation of additional variables into mathematical models.

Stock Assessment

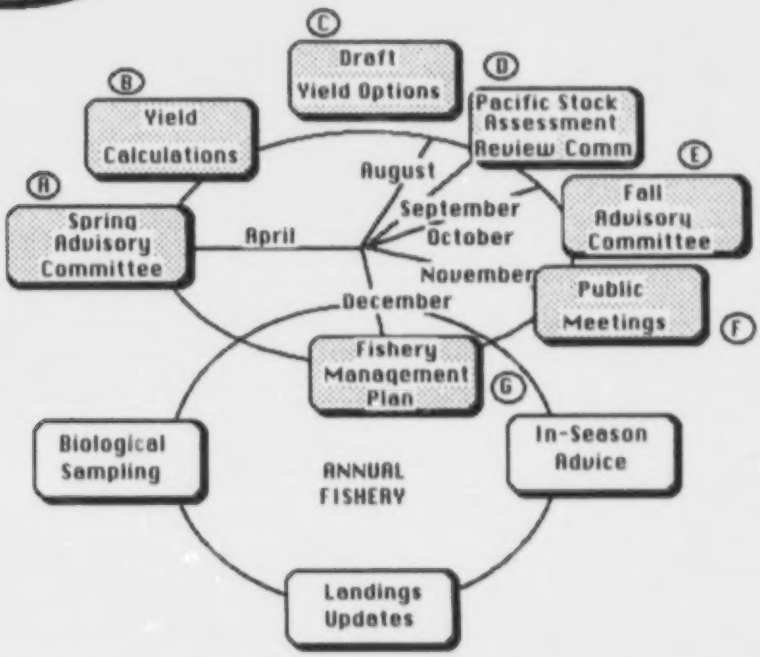
Biologists begin groundfish assessments in the spring of the year using a multi-year data base for fishery statistics and biological research. A variety of assessment models are used including: sequential analysis, age-independent surplus production, yield-per-recruit and linear models . Assessments are completed in August after review by a committee of groundfish scientists . Review may also incorporate outside investigators (government or non-government). Assessments are then reviewed by the DFO PSARC and recommended yield options are sent to fisheries management staff.

In early October, fishery managers and BSB biologists meet to review a draft management plan. It is at these meetings that alternative management scenarios are examined and their impacts assessed. A management plan is finalized and presented first to the Pacific Groundfish Advisory Committee (government and industry) and then to industry as a whole at public meetings in Vancouver and Prince Rupert in early November.

This review and consultation cycle is augmented by ad hoc meetings with industry representatives to address specific issues dealing with groundfish stock assessments. In addition, an annual meeting is held with industry to review research activities leading to the preparation of assessments and development of yield options for management recommendations. (*Contact: A.V. Tyler.*)



Sources of information and methodologies used to determine groundfish stock assessments.



Annual cycle for groundfish stock assessment proceedings.

Pacific Hake

Field studies included continued monitoring and biological sampling of Pacific hake in the Strait of Georgia using commercial samples, assessment of relative abundance and distribution off the west coast of Vancouver Island and a species interaction trawl survey conducted in August to assess the impact of sablefish and Pacific hake on the herring stocks in the La Perouse Bank region.

Results of this and previous surveys conducted to examine the relationship between ocean conditions and the estimated food rations of some major groundfish species indicated that herring year-class strength was most sensitive to changes in the diet of adult hake. These studies also suggest that sablefish, particularly juveniles of a strong year-class, may be an important predator of juvenile herring.

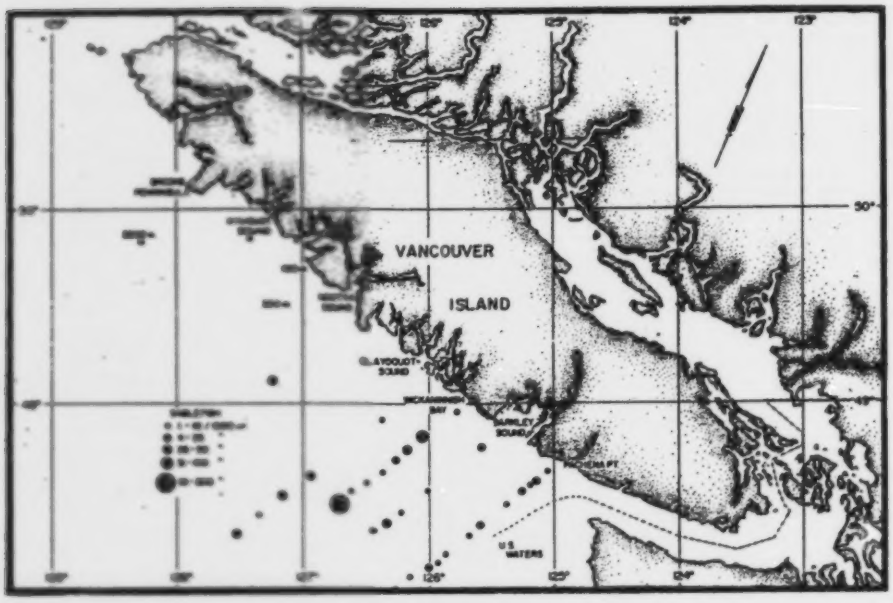
Laboratory work involved initiation of a study of reproductive response of Pacific hake to exploitation and an analysis of size at age over time for Strait of Georgia and offshore stocks which indicated that significant changes have taken place. In addition, a study to further examine the consequences of these changes on stock production was started. *(Contact: G.A. McFarlane.)*

Sablefish

Biological monitoring continued utilizing observers and a chartered commercial vessel. A survey examining the relative abundance and distribution of sablefish larvae off the west coast of Vancouver Island was conducted in April and May. Over a three year period there has been a two- to eight-fold difference in larval success as indicated by presence of larvae in surface waters. Correlation of this index with abundance in the fishery will begin in 1988.

Other studies involved the rearing of larval sablefish from eggs through to feeding larvae, examination of factors determining the production of strong year-classes, a co-operative parasite study, initiation of multi-variate analysis of trap catch/effort data to determine if it is an appropriate index of abundance for the stock, and an in-depth analysis of the tagging database to estimate short and long-term rates of immigration and emigration.

Eggs were collected at sea for the rearing study. The eggs were fertilized and incubated at temperatures ranging from 4 to 6°C and salinities from 31 to 34 parts per thousand. Larvae hatched in 11 to 16 days with yolk sac resorption complete by 30-34 days after hatch. Experiments to determine food preference, particle size and presentation in time were conducted. Larvae began feeding actively prior to full yolk sac utilization. Egg and larval densities were measured daily. This information was used to infer egg and larval depth distribution in the ocean.



Distribution of sablefish larvae from neuston tows, April 3-18, 1986. Abundance expressed as numbers per 1000m³.

The parasite study outlined the life history features of both host and parasite (intestinal trematodes); parasite incidence shows promise as a tool for stock delineation. Analysis of immigration and emigration rates from tagging data indicated that sablefish could be managed as a single stock.

The tagging analysis was based on a total of 72,735 adult fish tagged and released off the west coast of Canada from 1977 to 1982. As of December 31, 1985, 11,212 (15%) were recovered. It was concluded that sablefish constitute one population in the northeast Pacific with the centre of abundance in the southern Gulf of Alaska. It was found that movement out of any area is slow, making area-specific management possible.

A multivariate analysis of the trap catch/effort data was initiated and preliminary results will be presented in the 1988 stock assessments. The data were standardized to one gear type such as conical traps. These results indicate that the standardized CPUE follows similar trends as compared to the nominal CPUE. The results are considered preliminary and a report describing the analysis will be submitted for review. (*Contact: G.A. McFarlane.*)

Spiny Dogfish

Field work involved the initiation of a longline survey of the Strait of Georgia. The purpose of the survey, to be conducted triennially, is to establish an index of relative abundance. As well, biological samples were collected for data on length, sex, maturity, spines and fecundity.

Laboratory studies included initiation of analysis of 1983 and 1984 tag recoveries from dogfish released from 1978 to 1984 and completion of analysis and reporting on the annulus development on the second dorsal spine and its validity for age determination. The validation study resulted in a slight modification of the age determination methodology and indicated that dogfish are longer-lived and slower-growing than previously believed. (*Contact: M. Saunders.*)

Slope and Shelf Rockfishes

Understanding the stock structure of deep-water slope rockfishes off British Columbia is difficult because the fish cannot survive a normal tagging procedure. As an alternative, the infection of the most commercially important rockfish, Pacific ocean perch (*Sebastes alutus*), with the copepod gill parasite *Neobrachiella robusta*, was examined to ascertain its usefulness as a biological tag. Copepods taken from five presumptive stocks showed differences in the prevalence and intensity of infection as well as in their population structure indicating that these characteristics could be used for stock identification. These results permitted separation within and between three heavily fished and two lightly fished stocks. The parasite was less useful as a stock identification character for individual fish. However, 43-87% of individual fish could be correctly assigned to stock units when examined with discriminant function analysis. (*Contact: B. Leaman.*)

Research into the reproductive biology of long-lived rockfishes continued during 1986. Assessment of interannual variability in oocyte production, weight and diameter among five stocks of Pacific ocean perch with differing exploitation histories was initiated. Comparison with 1982 results showed that variability in individual oocyte characteristics was lower than in oocyte production. Simulation modelling of reproductive performance and population dynamics in response to fishing mortality indicated that monitoring the reproductive value (expected lifetime reproductive output) of recruiting fish, or other specific ages, will provide for more sensitive indices of stock condition than simple biomass-based measures. (*Contact: B. Leaman.*)

An alternative method for obtaining mortality rate information from length data was developed. Length data for silvergrey rockfish (*Sebastes brevispinis*) was examined with a population model which incorporated random variation in recruitment and length. The modelling exercises indicated that the expected length distributions were

relatively insensitive to year-class variability. Mean size was sensitive to variations in instantaneous total mortality, partial recruitment and growth. However, the shape and location of the right-hand limb of the curve was still a better indicator of total instantaneous mortality than mean or median length. These graphically-determined estimates based on length corresponded well with estimates derived directly from the age composition. (*Contact: R. Stanley.*)

Inshore Rockfish and Lingcod

The handline/troll and longline fisheries for inshore species of rockfish has grown rapidly in recent years. The first stock assessment for this species group was completed in 1986. Due to the lack of biological data, the assessment was based largely on historical trends in landings and landings per unit effort. To obtain a broader biological base for future assessments, research was extended in a number of directions. A new model was developed that compared research fishing data with densities of rockfish as determined by SCUBA survey. Fishing catch rates and densities were linearly related for quillback rockfish (*Sebastes maliger*). Hence, catch rates from survey fishing can be used as an abundance index. In addition, biological sampling of the commercial fishery landings was continued, a fecundity study was initiated and three survey cruises were completed in different areas of the fishery.

To improve the biological basis for stock assessments, work was also conducted on lingcod stocks. This included a survey in the Strait of Georgia, designed to improve our understanding of decreases in commercial landings in that area. A major analysis of existing biological and fishery data was initiated for stocks off southwest Vancouver Island which account for the majority of British Columbia lingcod landings. The analysis will utilize recent advances in stock assessment methodology to determine the biological impact of the fishery and appropriate harvest levels. (*Contact: L. Richards.*)

Flatfish

Field work was confined to a study of the reproductive biology of English sole in Hecate Strait. The first in a series of research cruises for this three-year project was conducted in November. Ovary samples were preserved for histological study and data for producing frequency graphs showing maturity stages were collected. Maturity stages indicated an October spawning in Hecate Strait during 1986. Lengths at 50% and 100% maturity for English sole females were 34 and 40 cm respectively.

Work was completed on the results of the 1982 rock role tagging experiment with

respect to stock delineation, growth and mortality rates. Results suggest that at least two populations of rock sole occur in Hecate Strait, one occupying the northern half while the other is resident in the southern portion. Estimates of instantaneous total mortality rate (Z) derived from the experiment were >1.0. As the fishing mortality rate for the species was relatively low over the study period (<0.3) it would appear that a significant increase in the natural mortality rate (previously estimated at 0.25) occurred in the early 1980s. The reasons for this higher rate are unclear at present, but the rock sole stocks in Hecate Strait are currently at very low levels.

Study of biological data indicated that English sole recruitment in Hecate Strait is increasing while rock sole recruitment remains at low levels.

Analysis of the results of the 1983 English sole tagging experiment is currently underway and English sole age validation results will be available in 1988. (*Contact: J. Fargo.*)

Pacific Cod

Stock assessment activities included compilation of 1985-1986 port samples, length-frequency data (from which ages are subsequently determined analytically), calculation of standardized landing statistics utilizing a method of allocating effort and relative fishing power factors to data for Pacific cod and its co-habitants, and stock assessment of Pacific cod in the Strait of Georgia using results of a study, including yield-per-recruit analyses, on relative fishing power of trawlers. None of the four stocks examined showed signs of recruitment overfishing. The mixed-species fishery precludes maximizing yield per recruit by mesh regulation. (*Contact: A.V. Tyler.*)

Statistics and Sampling

Commercial catches of groundfish continued to be monitored at dockside. Port samplers collected biological samples from commercial landings representing all the important trawl-caught species and recovered tags and logbooks from trawl, trap and longline vessels. Development of a computerized measuring board was completed and introduced on the Vancouver waterfront. Individual fish lengths and associated data can now be recorded directly onto a microcomputer.

Field tests of a computerized logbook system for trawlers continued. The system links a simple catch logger to a microcomputer-based plotter. Fishermen are able to enter catch by species and have the data linked to automatic bridge log recording. The system will not only provide skippers with computerized access to their historical fishing records but will also provide the database manager with logbook data in a

machine format. In the long term, it is also hoped that the skippers may be encouraged to record additional oceanographic or biological information.

The Unit continued to maintain a high resolution catch and effort database for all major groundfish fisheries excluding halibut. The database serves not only the research needs for stock assessment but is produced in a timely enough fashion to satisfy real-time management needs. (*Contact: R. Stanley.*)

Shellfish

The Shellfish Section provides biological and scientific advice for managing, protecting and developing the region's invertebrate resources with specific functions as follows: to undertake research on the distribution, life history, ecology, physiology and behaviour of commercial and potentially commercial invertebrate and marine plant species; to carry out resource surveys and sampling of commercial catches for stock assessments of invertebrate and marine plant species; to participate in research on the impact of natural and man-induced factors on the habitat of invertebrate and marine plant stocks; to maintain fishery databases and to develop analytical methods, including the use of theoretical models; and, to provide biological advice to management staff and to communicate research results to fishermen, industry and the scientific community.

Stock Assessment

Monitoring of an experimental prawn management system in Howe Sound was initiated. Surveys before and after the fishing season were conducted to establish the overall status of the stock and to evaluate the impacts of fishing strategies. (*Contact: J. Boutillier.*)

Research to develop and evaluate gear modifications to reduce the mortality caused by fishing of sub-legal size prawns was completed. (*Contact: J. Boutillier.*) This work was conducted at the request of industry and fishery managers to help develop a management strategy which prevented harvesting of sub-legal size prawns. Recommendations on minimum trap mesh size were subsequently adopted.

A review of the shrimp trawl fishery was prepared outlining both problems and potential solutions associated with assessing and managing stocks. A mandatory logbook system was initiated in an effort to obtain improved information for stock assessment purposes. (*Contact: J. Boutillier.*)

A multi-attribute decision-making study was completed to determine where sam-

pling of commercial invertebrate catches should optimally be conducted. Seventy-six invertebrate fisheries were considered in the exercise to identify which should be sampled to maximize return (a combined measure of benefits in relation to sampling costs). (*Contact: J. Boutillier.*)

A stock assessment for the Sooke coonstripe shrimp (*Pandalus danae*) trap fishery was conducted and a harvest strategy recommended. (*Contact: J. Boutillier.*) In addition, preliminary work on the distribution of the prawn parasite *Sylon* in the north coast was completed. This work may lead to restriction on the live transport of prawns from infected areas. (*Contact: S. Bower.*)

Fishing performance and species biology of both targetted (flying squid, *Ommastrephes bartrami*) and by-catch species were monitored in an experimental driftnet fishery in offshore waters. While results are still being analyzed to determine the temporal and spatial aspects of species distribution, the general catch results have been published. (*Contact: G. Jamieson.*)

Recruitment Studies

Aspects of the biology and early life history of Dungeness crab *(Cancer magister)* were investigated in the intensive fishery off Tofino on the west coast of Vancouver Island. The first component was the determination of the population structure and dynamics of both pre-recruit and recruit crabs and an assessment of the impact of the commercial fishery. Traps, trawls and tags were used in monthly surveys to follow crab movement and to monitor seasonal and annual shifts in population structure. Commercial crab fishermen actively participated in this program. The second part involved establishing factors influencing the presence of larval crab in the study area. Dungeness crab larvae drift as plankton for three to four months before settling as juveniles in shallow, nearshore areas. During this time, they are typically transported up to 180 km offshore by processes which are poorly understood, but which may determine the success or failure of larval crabs to settle in an area and eventually recruit to the fishery. In June 1986, the spatial distribution and abundance of late stage larvae from shore to 120 km offshore was monitored using surface plankton nets. Surface water movement was simultaneously monitored using radio-tracked drifting buoys in a joint study with CHS. Results showed an oceanographic boundary about 30 km offshore with larvae abundant seaward of this zone but scarce shoreward. No significant larval crab settlement was recorded in the Tofino area in 1986. The current fishery in Tofino is being sustained by a declining abundance of older crabs which settled in 1982 and 1983. Adult crab movement is limited and non-directed, indicating that the status of the resource around Tofino is unlikely to improve in the near future as a result of immigration of legal-size crabs into the fishery. (*Contact: G. Jamieson.*)

In Howe Sound, a preliminary study of juvenile prawn habitat to increase understanding of habitat utilization in shallow inshore waters was completed. Juveniles

occupy shallower water habitats than do adults but show considerable vertical mobility in the top 60 m. Male prawns appear to migrate deeper with age and eventually change their sex in deep water. These preliminary results have led to initiation of a study on larval prawn biology. *(Contact: J. Boutillier.)*

A recruitment study of the sea urchin, *Strongiyocentrotus franciscanus*, was completed along the east and west coasts of Vancouver Island. Recruitment was low, about 9.5% overall, compared to populations from lower latitudes. On a fine scale (0.5 to 8.0 km), recruitment was extremely patchy and clearly very dependant on site specific characteristics. Young recruits hide under adults, which, along with a strong tendency to aggregate, adds a complication in evaluating the effects of harvesting in this rapidly developing fishery. *(Contact: G. Jamieson.)*

Aquaculture Bivalve Nutrition

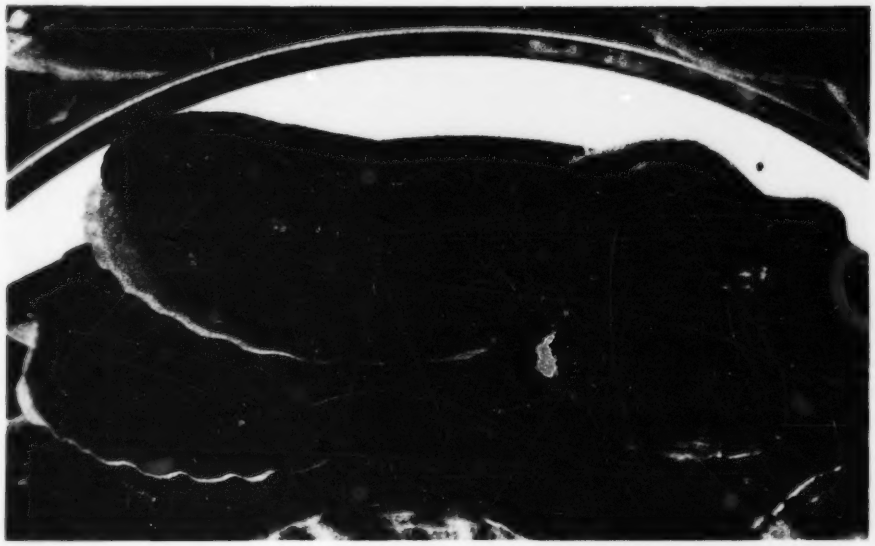
The lipid, carbohydrate and protein contents of six species of phytoplankton, cultured in the laboratory as food for scallop larvae and spat, were assessed and the corresponding energy equivalents calculated for these algae at both exponential and stationary phases of growth. Flagellates were shown to be ready sources of lipid and protein and diatoms a reliable source of reserve glucans, considered digestible by bivalves. Caloric content of constituent biochemicals allowed ranking of species as sources of energy, with the flagellates generally higher than the diatoms. This information is being evaluated in feeding trials with Japanese and rock scallops.

Binary and ternary mixtures of phytoplankton fed to larvae demonstrated varying growth patterns which were correlated with energy content of both the algal feed mixtures and the nutritional condition of the premetamorphic larvae. Utilization and assimilation of storage components in Japanese scallop larvae during growth and development, and under conditions of food deprivation, were assessed. Information obtained indicated the percentage of readily catabolized lipid, carbohydrate and protein available in larval tissue, which suggested the dietary requirements of scallop larvae needed to improve survival during the intense morphogenic activity of metamorphosis. (*Contact: J.N.C. Whyte.*)

Scallop Culture

Research effort in scallop culture during 1986/87 was directed at two species, the exotic Japanese scallop (*Patinopecten yessoensis*) and the native rock scallop (*Crassadoma gigantea*). Both species are large, have rapid growth rates and can be successfully spawned. In 1986/87, the number of successful spawns with Japanese scallops was almost the same as the previous year but production of fertilized eggs

increased 85% to 446 million, the result of perfecting methods to condition and spawn scallops. Survival from fertilized eggs to straight hinge stage was similar to the previous year, with 14.5 million mature larvae produced, an increase of 30%. About 7,500 juveniles larger than 5 mm shell height have been produced to date.



Patinopecten yessoensis *adults.*

Fewer spawns of rock scallops were attempted but 25% more eggs and 75% more straight hinge larvae were produced compared to the previous year. Four hundred percent more larvae were set and over 4000 juveniles larger than 5 mm produced. (*Contact: N. Bourne.*)

A major emphasis in 1986/87 was research into nutrition levels of scallop larvae and spat. About half the Japanese scallop larvae produced were used in nutritional studies, as described above. Studies of diet effects on larvae were completed and a diet of two diatoms, *Chaetoceros calcitrans* and *Thallasiosira pseudonana*, plus a flagellate, Tahitian *Isochrysis*, was found to produce better growth and survival of larvae than when these phytoplankters were given singly or in pairs. (*Contact: J.N.C. Whyte.*)

In previous years, high mortalities of larvae, particularly in juveniles from 0.3 to 1.0 mm shell height, have been experienced. Studies were begun to improve nursery technology and to increase growth and survival of juveniles. Experimental work was initiated to determine whether chemicals such as potassium chloride and the neurotransmitters GABA and L-DOPA would stimulate metamorphosis. Several

setting substrates for larvae (cultch) were tested and the best one was found to be an artificial fibrous material, kinran.

Juvenile Japanese scallops produced in the previous year were used in grow-out trials in 1986/87. Grow-out was carried out at three depths, 5, 10 and 15 m, at Departure Bay and Refuge Cove, to assess growth and mortality rates until they reach commercial size (10 cm shell height). Mortality was about 1-2% per month, except in September-November when mortality was slightly higher. Growth of juveniles was least at 15 m and greatest at 10 m. Slower growth at 5 m may be due to heavier fouling of the nets at this depth. Best growth of Japanese scallops was in Departure Bay, to 11 cm shell height in 18 months, with a mean growth of 8-9 cm shell height for the same period. Results indicate it is possible to produce a commercial size Japanese scallop in British Columbia within two years.

Some of the Japanese scallops produced in 1985/86 and grown to commercial size in 1986/87 were used as broodstock in 1987. It is now no longer necessary to import broodstock from Japan.

Juvenile scallops produced in the current year will be used in grow-out experimental work at seven locations along the British Columbia coast in 1987/88. (*Contact: N. Bourne.*)

Mussel Culture

Growth and mortality rates of blue mussels, *Mytilus edulis*, were compared in four experiments. To assess site effects, mussels were grown at 18 sites throughout the province, from Sooke to Prince Rupert. Seed from eight sources was also grown at both Departure Bay and Tofino to assess potential genetic and environmental effects. To determine the relative interaction of environment and genetics, mussel seed from three stocks was collected and then grown at each of the three sites. The importance of intertidal exposure in mussel grow-out was determined by comparing survival and growth of both blue and sea mussels (*M. californianus*) grown in the intertidal and subtidal zones.

In addition, the reproductive condition of *Mytilus edulis* grown in each of the experiments was monitored.

Results showed that some sites were better for growing mussels than others. In addition, when grown under the same conditions, mussels from some populations had higher growth and survival rates than others, indicating that both stock and grow-out site are important factors. In addition, the three-site transplant experiment showed that in some cases, mussels from one site grew and survived better when transplanted to a new site than at their original site. *Mytilus edulis* grown in the intertidal zone had a higher survival rate than those grown subtidally, but subtidal *M. edulis* grew at a faster rate. Finally, *M. californianus* had a much higher rate of survival than *M. edulis* grown under the same environmental conditions. (*Contact: G. Jamieson.*)

Herring

The primary objective of herring research at PBS is to provide the scientific basis for the conservation and rational management of this resource in B.C. In order to provide biological advice on stock status and catch recommendations for herring fisheries, the major focus of research in recent years has been stock assessment related. This work includes development and evaluation of analytical assessment methodology, development of spawn survey techniques, analysis of the historic spawn database and stock identification research.

Analytical Assessments

Two analytical assessment models, developed explicitly to conduct annual assessments and forecasts for B. C. herring stocks, were used in 1986/87. Major modifications were made to both models this year to incorporate additional data and to make the models as consistent as possible with the life history of the species and the nature of the fisheries. The escapement model, which is based primarily on information from diver spawn surveys, was revised to include age composition data. This allowed separation of stock production into growth and recruitment components, thus providing more realistic estimates of historic recruitment. The age-structured model was reformulated as an availability model which is more consistent with the herring life history where only sexually mature, i.e. spawning fish, are available to the fisheries. (*Contact: V. Haist.*)

Analysis of historic recruitment estimates, obtained from analytical assessments, led to the development of recruitment models for major herring stocks. The Ricker model, the Ricker-Environment model and the Transfer Function Noise model were evaluated. For each stock the model which provided the best fit to the historic data was used to make numerical recruitment forecasts for 1987. (*Contact: M. Stocker.*)

To provide the information required for stock assessment, an annual stock monitoring program is conducted and a database of historical data from 1950 to the present is maintained. During the 1986/87 season, 88 samples from nine commercial roe fisheries, 264 prefishery charter samples and 28 research samples were collected and processed for biological data. In addition, 14 samples were collected for morphometric and electrophoretic analysis which are now being analyzed for stock separation characteristics.

Spawn Surveys and Analysis

Herring deposit eggs which adhere to intertidal and subtidal marine vegetation. Surface surveys of this spawn have been conducted by Fishery Officers since the 1940s, and the data used as an index of abundance in stock assessments. More recently, dive surveys have been developed at PBS to precisely and accurately estimate egg deposition, from which adult spawner biomass is calculated.

Two categories of dive surveys were conducted in 1986/87. Research surveys, conducted off the northern B.C. mainland, were designed to refine survey design and to evaluate area and year differences in egg deposition patterns. Spawn samples are currently being processed to obtain egg counts; this information will be included in the database to improve a predictive model for egg density based on observational data only.

A modified version of the research dive survey was used for the first time by Fishery Officers on the south coast in place of the surface assessment methods. While these surveys were strictly observational, i.e. spawn samples were not collected for analysis, they provided more accurate estimates of spawn deposition than standard surface methods. Herring research staff will continue to assist the Fisheries Branch in the diver training, sampling design and data analysis for these visual dive surveys to ensure coastwide implementation. (*Contact: C. Haegele.*)

Maps of marine vegetation, based on aerial photographs, are used in spawn surveys to record and assess spawn survey information. A project was initiated in 1974 to map the shoreline vegetation on 15 major herring spawning grounds. The project is almost complete with maps for the upper west coast of Vancouver Island, prepared from photographs obtained in April 1981, published in 1987. Photographs obtained in March 1982 for the lower west coast of the Queen Charlotte Islands were processed to the working map stage in 1986/87. (*Contact: C. Haegele.*)

Analysis of historic herring spawning records was completed in 1986. The data were based on nearly 20,000 Fishery Officer records of the locations and dates of herring spawning. These data were analyzed to show the most important herring spawning locations on the coast and the relative magnitude of spawning was compared. These analyses have been incorporated into the annual herring stock assessments and also have proved to be useful for assessing potential impacts of industrial developments, especially oil exploration activities and fish farming. (*Contact: D. Hay.*)

Forecasting Spawn Timing

The challenge for managers of the herring roe fishery is to stage an opening when the herring are fully mature, but before spawning begins. The ability to forecast when herring will reach full maturity and spawn would be an invaluable manage-

ment tool. Results of a preliminary study conducted in Barkley Sound in 1982 indicated that the gonosomatic index (GSI), i.e. the percentage of total fish weight made up by the ovary, could be used to predict herring spawn timing. Briefly, the forecasting procedure consists of monitoring the rate at which GSI increases and then estimating when females will be fully mature.

In-season data have been obtained and forecasts made for selected stocks since 1982. In some instances, spawn timing was predicted accurately; the inaccuracy of the other forecasts resulted in part from the inability to separate different maturity groups and because the influence of the tidal cycle on spawning was not known. This year, a variation of the original procedure was developed to deal with instances where more than one maturity group occurs in the sampling area. Analyses of data from the herring stock monitoring program indicate that: spawning outside the Strait of Georgia generally occurs during the neap tide with fish holding at full maturity until the appropriate period of the tidal cycle; there may be pheromonal communication between the sexes with respect to the state of maturity which, in turn, influences spawn timing; and maturation rates may be modified by temperature, weight and sex. Field tests of the method are continuing. Researchers hope the improved procedure and recent findings regarding factors affecting spawn timing will result in a better forecasting tool. (*Contact: D. Ware.*)

Northern Surveys

For several years herring research in northern British Columbia waters has been conducted as part of the Hecate Strait Project. Herring surveys have been conducted during the summer, winter and spring. The summer surveys were designed to study herring distribution relative to the abundance of planktonic food organisms. The winter surveys investigated winter distributions and examined the feasibility of hydroacoustically estimating biomass at that time of year. The spring surveys were designed to determine the distribution of herring larvae to see if they were an important factor in trophic relationships in small Hecate Strait fishes.

A number of interesting and useful results have been documented to date. There appears to be a one-to-one correspondence between the major winter distributions and the major spawning distributions. Also, herring biomass estimates, made hydroacoustically, were similar to those from the two analytical methods used for stock assessment. This agreement provides further support to present stock assessment methods and indicates that hydroacoustic surveys may have practical applications in some circumstances.

The larval surveys have shown that larval herring distributions are mainly limited to nearshore waters, rarely extending beyond several kilometres into the open sea. On the other hand, the larval distributions were spread substantially along the shoreline. In several locations, larval distributions were continuous along the shore although they were derived from several different spawning sites. This indicates that

the herring from these different spawning sites probably are part of the same biological stock. (*Contact: D. Hay.*)

Salmon-Herring Interactions

There has been a long standing view on the part of some sports fishing groups and salmon fishermen that commercial harvest of herring could affect abundance of chinook and coho stocks, the main predatory salmonid species. An alternative opinion is that salmon, especially enhanced stocks, could prey heavily and possibly limit production of juvenile herring in some locations.

Beginning in 1986, a study was initiated to examine the relationship between salmon and herring, with the emphasis mainly on Georgia and Johnstone Straits. This relationship has been studied in the past but has not received much critical attention for about 10 years. The intent of this project was to re-examine questions about salmon-herring interactions in light of revised abundance estimates and recent information about herring life history, migrations and stock structure. In addition, more stomach data were collected from key sports fishing locations.

Preliminary analysis of data indicate that in some locations, and at some times, herring comprise up to 40% of chinook diets. The significance of this observation, however, will await further data collection and analysis. (*Contact: D. Hay.*)

Ocean Ecology

Plankton

Plankton research activities in 1986 were influenced by two factors. Cruises were undertaken to study processes important to the ongoing La Perouse Project and to the pending Marine Survival of Salmon (MASS) study, both off the west coast of Vancouver Island. In addition, high frequency underwater acoustics were used for the first time to map distributions of euphausiids (small shrimp-like zooplankton) and satellite images of ocean surface temperature were transmitted to researchers onboard ship within 24 hours of reception to aid in sampling time-varying physical and biological phenomena.

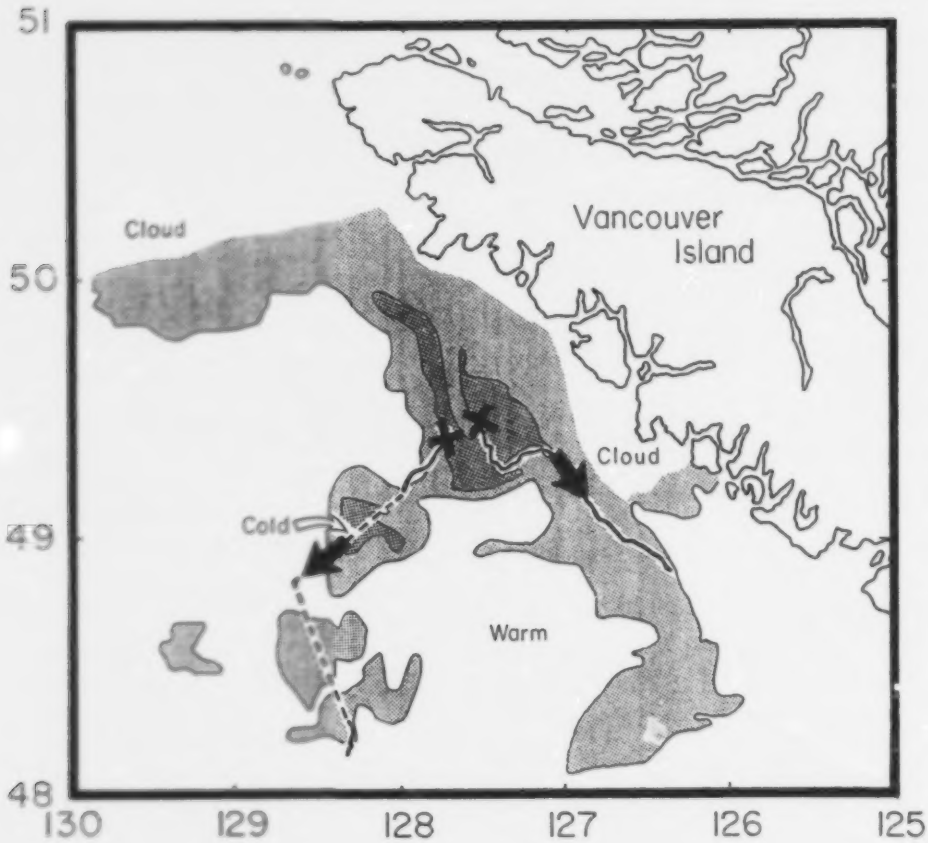
In June a cruise was carried out over the La Perouse Bank region and adjacent to the mouth of Juan de Fuca Strait where a counterclock-wise circulation gyre is often found during summer months. This co-operative cruise was the sequel to a similar

expedition in 1985 and involved scientists from Tides and Currents and Shellfish Sections.

The objectives were to: deploy drogued drifters in and near the gyre; determine whether they escape the gyre and the shelf region, advecting with them populations of zooplankton and phytoplankton; and, determine daily physiological and behaviour cycles in the plankton populations following the drogued water parcels. Indications were that the gyre is episodically present and absent (or not well formed) for periods of days at a time. The mean residence time for drogues and plankton over the adjacent continental shelf was found to be three to five days before they are advected or swept into deeper water and/or up or down the coast and hence lost as a food source to the local demersal and salmonid fish species. Larger crustacean zooplankton (euphausiids) are capable (as adults) of extensive vertical migration, spending daylight hours below the strongest currents, thereby perhaps reducing their exposure to the current patterns followed by the drifters. The map of euphausiid distribution obtained by Dr. Yvan Simard using high frequency acoustics showed the euphausiid layer to be in a band along the coast just off the edge of the continental shelf and in the deeper canyon system penetrating towards Barkley Sound. This band approximately matches the zone of strongest alongshore currents. In daylight, the scattering layer was concentrated below a depth of 80 m and did not extend onto any of the shallow banks. Time series of measurements of abundance and growth rates of the microscopic plants in the ocean (phytoplankton) were also carried out while the ship followed individual drifters. By sampling the same population in the water mass tagged by the drifter, researchers hope to resolve the daily cycles in growth rate and other physiological indicators such as fluorescence well enough to correct for them in measurements made during spatial surveys such as the La Perouse station grid.

In August, a study of an upwelling filament off Vancouver Island was carried out. These filaments are tongues of newly-upwelled water that flow offshore from the coast carrying with them nutrients, plankton and possibly juvenile fish. The objective of the study was to evaluate their potential for disrupting the northward-flowing Vancouver Island Coastal Current, in which juvenile salmon from Barkley Sound are postulated to migrate to the subarctic northeast Pacific. Satellite imagery indicated that cold water off northern Vancouver Island was detaching itself from the coast near Brooks Peninsula. With the aid of further satellite images, sent to the ship via the facsimile transmission system used to send weather maps, drogued drifters were deployed in the filament to follow its development. The filament split into an offshore flowing branch and a branch that flowed southward along the edge of the continental shelf. One week's sampling along both branches showed them to be cold, salty and nutrient-rich indicative of newly-upwelled water. The concentration of phytoplankton increased along the filament indicating that they were growing well in the nutrient-rich waters. From the drogued drifter speeds, ranging from 10 to 50 cm s^{-1}, and geostrophic transport calculations, it was estimated the transport of water and nutrients by this filament was at least 1/4 that estimated for the 1000 km-wide southward flowing California Current off California. During both these cruises, and on several other occasions, sampling of the La Perouse station grid was also undertaken. In cooperation with Dr. Mark Abbott (Scripps Institution of Oceanography), an analysis of Coastal Zone Color Scanner satellite images for the same region was

completed. With the aid of cross spectrum techniques, this analysis indicated that surface phytoplankton patterns evolve and lose significant statistical correlation over about seven to ten days. It is thus hypothesized that in a "patch" of water rich in phytoplankton, grazing by zooplankton on phytoplankton and subsequently by smaller fish on the zooplankton must take place within about 10 days before the "patch" is dispersed by the highly variable currents on and near the continental shelf. (*Contact: K. Denman, D. Mackas.*)



Tracks (heavy lines) of drifters drogued to follow near surface currents over a seven day period in August 1987. The Xs mark the points of deployment and the arrows, the direction of travel. The two shades of grey denote cool and cold surface waters flowing away from the upwelling centres near the coast. The sea surface temperature patterns were drawn from satellite thermal imagery.

Benthos

The 1986 season saw the completion of a number of large projects on the macroscopic fauna of soft sediments in relation to a number of applied problems. The surveys of Hecate Strait in support of a groundfish study of the food of a multispecies complex of fish were completed. The results show the benthos of the four regions to be quite different, but that there was good statistical agreement between the samples from any one area across the three seasons involved. A suite of new statistical tests, described below, were applied to the large data sets. Wet weight data was variable and inconsistent in contrast to the relative abundance data for the wide variety of taxa found (up to 355 per cruise). Abundance ranged up to a maximum of 560 per 0.1 m^2. An unidentified factor correlated with depth combined with proximity to other samples (i.e. area A samples were similar but differed from area B samples) accounted for most of the variability observed, whereas crude estimates of sediment type (% silt etc.) did not appear to be correlated with species abundance data. As well as linking to the simultaneous study of fish stomach content in the same areas, this data will provide a large, quantitative, taxonomically defined base for comparison with other work, some of which was also completed this year.

The similar large-scale study of benthic soft-substrate fauna off Barkley Sound was completed. Two distinct species assemblages were found, one inhabiting silt-clay substrates with relatively high carbon content and a second, further offshore, in sandy, low carbon sediments. Within these two areas, samples most closely resembled those from the next closest sample site, indicating a community that changes gradually, perhaps along an undetected gradient. There were few differences between the spring and fall cruises. There was no support for hypotheses relating benthic abundance or biomass to the productivity of the overlying water or to circulation differences related to a local gyre in the region. The two communities were quantitatively similar even though the taxonomic basis differed. This study was the second completed in an uncontaminated area.

The study of a shallower set of stations in Boundary and Mud Bays was initiated in response to concern about the possible linkage of grey whale deaths to an industrial spill in a tributary stream. Studies in the stream had indicated only local effects with rapid recovery. No trace of any problems could be found in the benthic study, carried out in association with Environment Canada personnel from EPS. The mean number of taxa (species or other groups) and of individuals reached 37 and 18,000 per m^2 respectively, and there was a normal diversity of animals in the sediment in most places. Three stations from deeper, siltier sites appeared to have richer fauna than the rest, and this was tested in a second survey.

In the fall of 1986, a cruise on the CSS JOHN P. TULLY was organized to investigate the state of recovery of Alice Arm from mine tailings dispersal. IOS and EPS scientists were joined by researchers from Royal Roads Military College, University of Victoria, University of British Columbia and by a scientist from Argentina. The results of the benthic infauna surveys well below the mine site and out into Hastings Arm showed complete recovery of the benthos in terms of species diversity and

abundance, but the actual species present at the most heavily affected sites caused those stations to cluster out separately, i.e. there is still a detectable effect according to this sensitive test. Chemical results will be reported elsewhere.

All of these studies made use of three statistical techniques devised by Drs. A.M. Nemec and R.O. Brinkhurst. These were designed to remove subjective judgements in the use of cluster analyses. They enable comparisons to be made between clusters based on field data and on arbitrary data derived, for example, on depth or geographic proximity (in order to detect the effect of site specific impacts), or comparisons between two different data sets (different areas or the same area at different times). The third test examined the significance of cluster groups within a single analysis. All of these allow statistical evaluation of what used to be subjective judgements.

A similar statistical approach is being adopted in systematics, the necessary basis for all of the ecological work described above. Dr. Nemec was also involved in a unique, detailed comparison of classical and recent techniques for classifying species. Modern cladistic techniques are also at the core of a Ph.D. degree recently completed by Dr. K. A. Coates at the University of Victoria under the supervision of Dr. Brinkhurst. Assistance with identification and confirmation of aquatic oligochaete specimens was provided, especially to the USA, Mexico and Australia. (*Contact: R. Brinkhurst.*)

Recruitment Mechanisms

The Recruitment Mechanisms Section was formed in 1986 to study recruitment processes in marine and freshwater ecosystems in response to the need for better understanding of the causes of variation in year-class strength (recruitment) of economically important fish and shellfish. The goal is to improve the accuracy of stock assessments and hence the numbers of fish available for harvest. The section research objectives are to: study the annual recruitment and reproductive processes of salmon, herring and groundfish; correlate effects of interannual and long-term changes in freshwater and ocean climate on recruitment processes; and determine how the species interactions of predation and competition influence recruitment trends.

The following programs, all longer-term and multi-disciplinary, reflect the nature of the research.

La Perouse

This program, begun in 1985, is designed to evaluate the influence of oceanographic factors on fish species interactions in nearshore waters off southwestern Vancouver

Island. The research is collaborative, involving physical and biological oceanographers from the Institute of Ocean Sciences and biologists from the Groundfish and Recruitment Mechanisms sections of Biological Sciences Branch. Scientists have concentrated on Pacific herring, examining the impact of offshore predators and the influence of biotic and abiotic factors on growth.

Field research in 1986 consisted of an investigation of the distribution and feeding of herring, Pacific hake, sablefish and dogfish during August. Special emphasis was placed on herring-hake interactions and the diel vertical movements and feeding periodicity of herring and hake. Preliminary results indicated that the diets of hake and dogfish differed from those in 1985, which could reflect changes in the abundance of age zero, one and two herring. Diel vertical movements of species and timing of feeding activity indicated that hake and dogfish feed most actively on herring when both euphausiids and herring concentrate near the surface after dark. The age composition of the herring captured offshore was used to forecast recruitment of sub-adult fish to the Barkley Sound spawning population in the spring of 1987, a forecast that proved to be within one percent of the observed recruitment.

A 56-year record of size-at-age for Barkley Sound herring was examined to determine the influence of various factors on growth. Time-series analysis indicated five-year and 20-year cycles in size-at-age. These cycles may be related to El Nino-Southern Oscillation (ENSO) events and long-term variation in ocean conditions. It is not clear whether these long-term variations in size-at-age are linked to fluctuations in herring stock biomass. (*Contact: D. Ware.*)

Marine Survival of Salmon (MASS)

This program was initiated late in 1986. Its objectives are to investigate oceanographic influences on survival of salmon during their first few months at sea. Like the La Perouse program, MASS involves collaboration between scientists at IOS, PBS and the West Vancouver Laboratory (WVL). Research will focus on three geographic regions where important physical and/or biological events are believed to occur. In the Alberni Inlet-Barkley Sound area, large stocks of sockeye, coho and chinook salmon experience the earliest phase of their marine existence. Here, the migration, dispersal, survival and growth of young salmon will be studied in relation to mixing and water exchange processes in Barkley Sound, local food production systems, and predator distribution and abundance. Off the west coast of Vancouver Island, juvenile sockeye migrate northwestward along the inner continental shelf. Their migration and survival will be studied in relation to the strength and integrity of the northward flowing Vancouver Island coastal current. On Swiftsure and Amphitrite Banks off southwestern Vancouver Island, young chinook and coho are known to aggregate during their first year of ocean life. The short-term survival of these species will be investigated in relation to eddy-trapping and food-producing mechanisms over the banks, while the longer-term persistence of chinook aggregations will

be investigated in relation to the spring and fall transition periods in ocean conditions. (*Contact: M.C. Healey.*)

Hecate Strait

This program, which began in 1984, is designed to develop the ecological basis for multispecies approaches to mixed species fisheries management in Hecate Strait. The Hecate Strait fishery, although small by world standards, can be regarded as a model of larger, less tractable, mixed species fisheries. The program is comprised of 12 inter-related projects, each of which focuses on some aspect of the fishery production system of the strait.

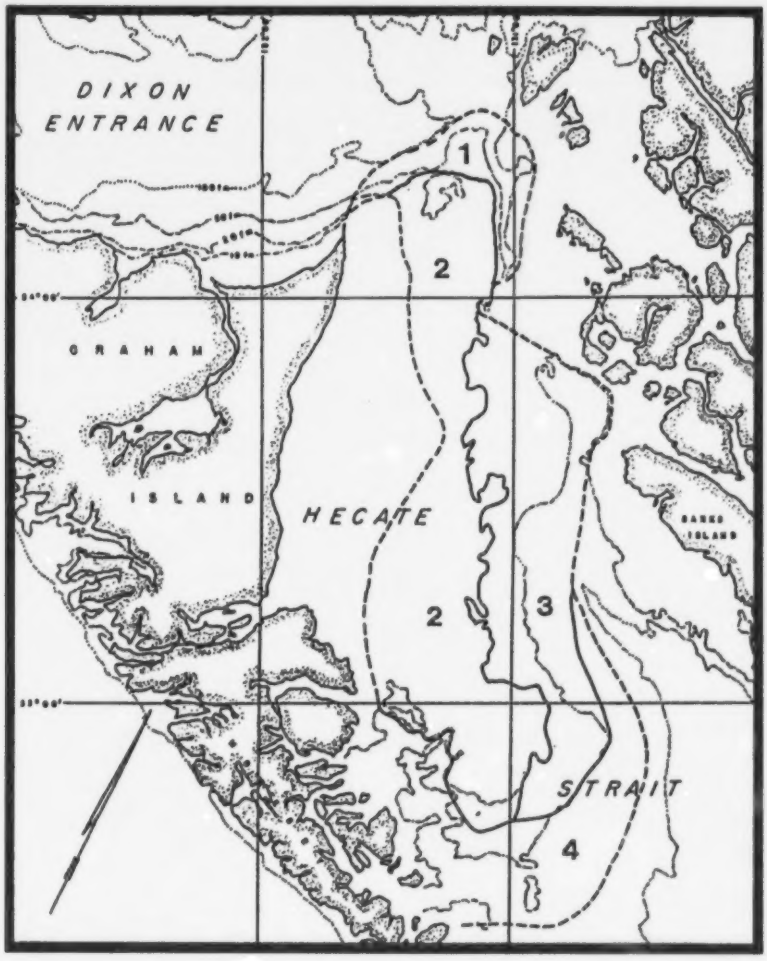
Research in 1986 included a species assemblage cruise conducted jointly with the Groundfish Section in February, and two summer cruises to determine juvenile salmon species and size composition. The assemblage cruise was designed to complement a 1984 early summer cruise.

Analysis of the two assemblage cruises by agglomerative clustering methods indicated that four assemblages dominated Hecate Strait in both the early summer and in the winter. While, the geographic boundaries and species compositions of the summer and winter assemblages were strikingly similar, the relative abundance of species within the assemblages varied seasonally. Northern Hecate Strait was dominated by ratfish and skate during the winter, whereas in summer arrowtooth flounder was most abundant, followed by Dover sole and spiny dogfish. Southern Hecate Strait was dominated by spiny dogfish in winter, due to their seasonal migration into the area, but was characterized primarily by rockfish species during the summer. It appears that the Strait is composed of four distinct geographic assemblages that show some seasonal variability due to translocations of a few species. In general, depth distributions and assemblage areas remained seasonally stable for the major commercial species - English sole, rock sole and Pacific cod .

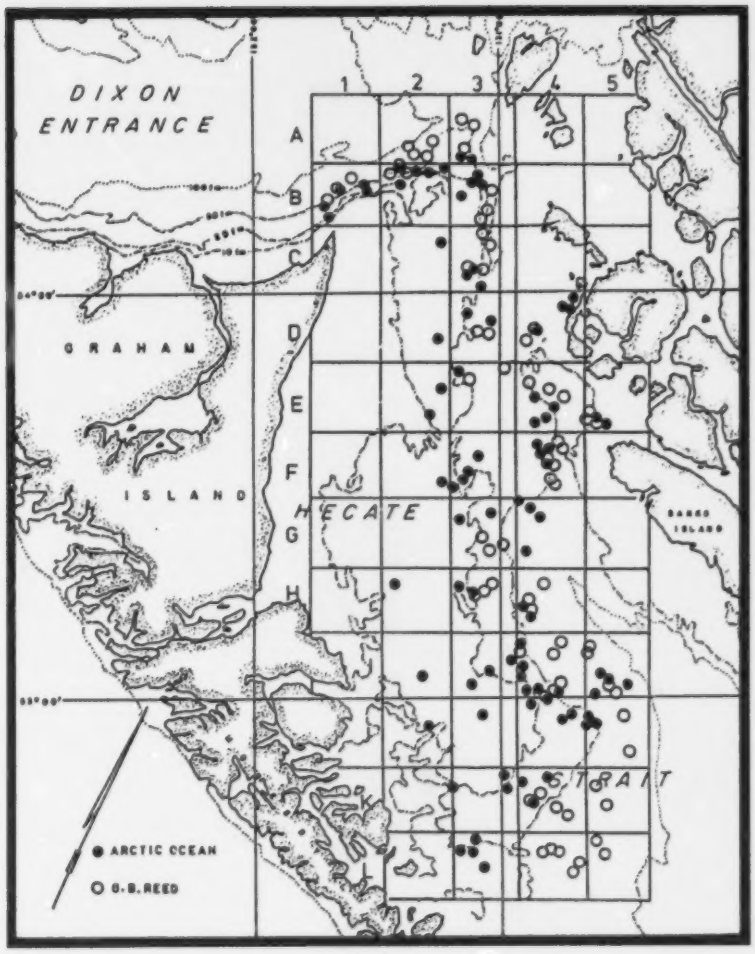
Based on preliminary analysis, four sites, each representing a species assemblage unit, were selected for intensive sampling of fish stomachs, surficial sediments, benthos and epi-benthos during the February cruise. Over 1300 stomachs from 23 fish species were collected. Laboratory analysis of several thousand fish stomachs collected during earlier cruises in June and September, 1985 and January, 1986 was conducted at PBS, while associated samples of sediments and benthos were analyzed at IOS. A computer data base has been established for these data and analyses are underway. (*Contact: A.V. Tyler.*)

Special emphasis is being placed on Pacific cod in connection with related work within the La Perouse program. Laboratory analyses consisted of the compilation of a new database for investigation of fluctuations in year-class strength in the Queen Charlotte Islands area. The database will facilitate statistical analyses of the effects of ambient temperature, water mass transport, spawning stock size and the availa-

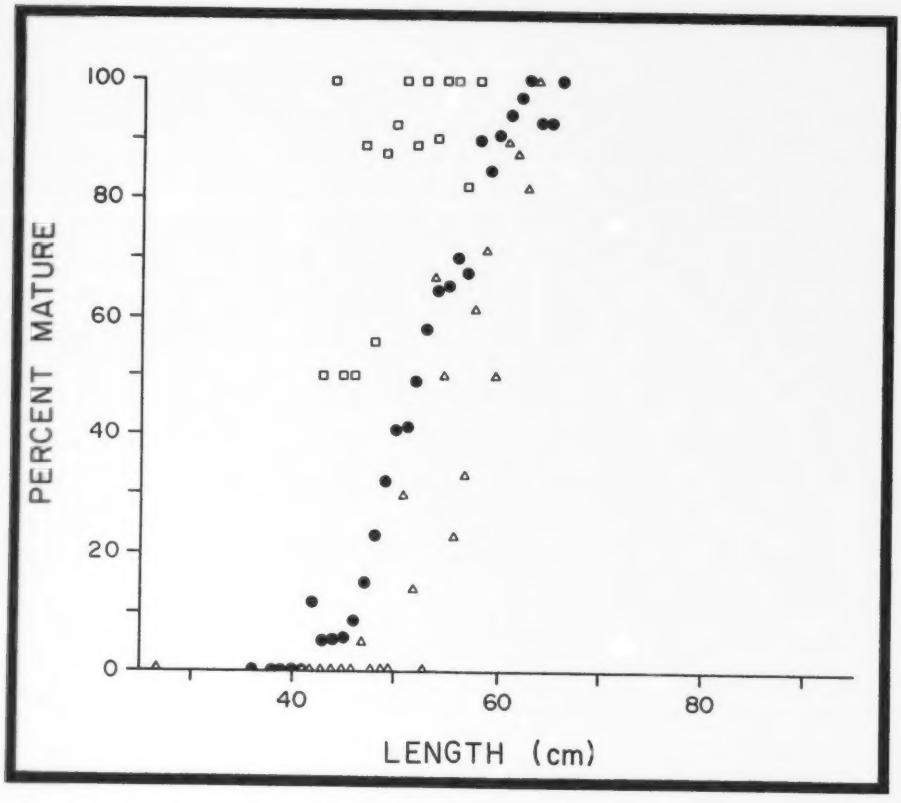
bility of herring as prey on year-class strength. In addition, a three-year study of the maturation cycle of Pacific cod in Hecate Strait and on La Perouse Bank was started. A cruise was conducted to Hecate Strait in November to take gonad samples for histological examination and fecundity studies. These samples, plus those from future cruises, will confirm or contradict the observation, based on commercial fishery sampling, that size at 50% maturation increases considerably from north to south within Hecate Strait . (*Contact: A.V. Tyler.*)



Assemblage areas defined by statistical cluster analysis of percentage biomass abundance of fishes taken during the May 24 to June 17, 1984 cruises of the ARCTIC OCEAN and G.B. REED at sites mapped in adjacent figure.



Trawl sampling sites for the May 24 to June 17, 1984 research cruises of the ARCTIC OCEAN and G.B. REED.



Length at which 50% of Pacific cod females became mature increased at progressively more northern sampling sites in Hecate Strait.

Hypotheses concerning the routes and timing of juvenile salmon migration along the coast were explored by a simulation model. Model predictions were tested by purse seining conducted during July and August. The species and size composition of juvenile salmon captured suggests that most juveniles were from production regions to the south of Hecate Strait and that these young fish were migrating north through the strait. (*Contact: M.C. Healey.*)

Fraser Lakes

The objectives of this program are to measure recruitment success, to investigate factors limiting production, and to determine methods for maintaining or enhancing sockeye production from Fraser River lakes. Emphasis is being placed on co-

ordinated research into interactions between trophic levels and the effects of lake physics and chemistry on production. Efforts in 1986 focused on Adams, Chilko and Quesnel lakes with some assessment work on Harrison Lake.

Preliminary observations of the physical, chemical and biological properties of Adams Lake indicated that it is an excellent candidate for fertilization, and should be seriously considered once the rehabilitation of Adams Lake sockeye has progressed sufficiently. Three years of data from Chilko Lake indicated that its productivity could be enhanced by fertilization with potentially beneficial effects on sockeye production. A hydroacoustic and trawl survey of the lake in August indicated that sockeye fry distribution was quite heterogeneous. Further investigation of fry distribution and growth are planned. In view of the near record escapement of adult sockeye to Quesnel Lake in 1985, 1986 studies were designed to determine the effects of high fry densities on all trophic levels. These studies will be repeated in 1987 when sockeye fry densities are expected to be low. Investigation of the carrying capacity of Quesnel Lake is essential for future enhancement, which may include combining spawning channels with fertilization. (*Contact: K. Shortreed.*)

Lake Enrichment - Food Web

Lake fertilization has become the predominant method for enhancing sockeye salmon production in British Columbia. Research objectives are to: determine correct fertilizer additions to candidate lakes, monitor the water quality and plankton responses to fertilizer additions and determine the mechanisms of energy transfer from primary producers through the food web to sockeye fry. In 1986, eleven sockeye nursery lakes were treated weekly with nitrogen and phosphorus fertilizers throughout May to September. Treated lakes were on Vancouver Island (Great Central, Sproat, Kennedy, Henderson, Nimpkish), on the central and northern coasts (Long, Bonilla, Curtis, Devon) and in the northern interior (Morice, Tahltan). Intensive limnological research on fertilized lakes was confined to Nimpkish and Sproat lakes. Of these lakes, Sproat is unique in that it has four distinct basins and an hypolimnetic chlorophyll maximum. Nevertheless, it appeared to respond favourably to epilimnetic application of fertilizer. There was a slight decrease in water clarity caused by the enhanced phytoplankton production which caused public concern about fertilization of this popular recreational lake. Consequently, fertilization applications were terminated in early July.

The working hypothesis behind the food web research in sockeye nursery lakes is that differences in sockeye growth and carrying capacity among lakes have a basis in differences in the lakes' food webs, which can enhance or constrain the effectiveness of fertilization as a tool for sockeye enhancement. In 1986, research focused on the rates of utilization of phytoplankton production by zooplankton and of size-dependent turnover rates and particle grazing rates in a coastal and an interior lake. These lakes, representative of their geographic regions, differ in their zooplankton communities and in their ability to support juvenile sockeye. Preliminary analysis

demonstrates the superiority of the interior lake's zooplankton community in rapidly and efficiently transforming primary production into high quality sockeye forage. (*Contact: E. MacIsaac.*)

Fish Health and Parasitology

The Fish Health and Parasitology Section conducts research on the identification, prevention and control of diseases of finfish and shellfish, particularly in culture facilities and fish farms; provides a diagnostic and consultative service on fish and shellfish diseases and advises on preventative and remedial measures; conducts research on fish parasites to minimize or reduce economic losses from their effects on fish health and on market acceptance of fish products, and on the use of parasites as natural biological tags for fish stock identification. (*Contact: L. Margolis.*)

Fish Health Research

Earlier work indicated that dip-administered anti-furunculosis vaccines confer low but measurable protection against this prevalent bacterial disease of cultured salmon. Ten adjuvants (or immunomodulators) were screened, using injection, for their ability to enhance resistance to furunculosis. At least three of them showed some promise. (*Contact: T. Evelyn.*)

Studies were undertaken to develop techniques for preventing the egg-mediated transmission of *Renibacterium salmoninarum*, the cause of bacterial kidney disease (BKD), considered to be one of the major constraints to growth of the salmon aquaculture industry in British Columbia. Initial research showed that injection of broodfish with the antibiotic erythromycin (20 mg/kg fish) 30-56 days prior to spawning, resulted in the presence of therapeutic levels of non-leachable antibiotic in the egg. Recent tests have shown that the antibiotic can be injected as close as 13 days prior to spawning with effective results. Direct treatment of eggs with erythromycin was also tested but was not as promising as the indirect method. (*Contact: T. Evelyn.*)

The industry practice of treating fish with antibiotics while handling them during vaccination against the bacterial disease vibriosis was examined for its effect on vaccine efficacy. Treatment with the antibiotic terramycin, administered by injection or by feeding, caused slight but measurable reductions in the fish's antibody response. In contrast, two other antibiotics tested (erythromycin and oxolinic acid), showed no such evidence of immuno-suppression. (*Contact: T. Evelyn.*)

Research on infectious hematopoietic necrosis (IHN) virus in sockeye salmon in the

Babine system revealed that "late run" spawners in five stocks showed a higher prevalence of the virus than "early run" spawners. Prevalence in "late run" fish ranged from 60% to 82%. Fry leaving spawning channels and a natural spawning bed were monitored for mortalities due to IHN following a brief four-day holding period. Mortalities in fry from two spawning channels ranged from 15% to 70% and 8% to 24% respectively, whereas mortalities from fry from the natural spawning bed were only 1% to 6%. High density spawning in artificial channels may be the cause of the higher mortalities due to IHN. (*Contact: T. Evelyn.*)

Experiments conducted at the Chehalis River Hatchery to investigate the cause of exceptionally high mortalities among chinook salmon fry revealed that the mortalities are almost certainly the result of an infectious agent, although the agent has not yet been identified. Studies have shown that mortalities could be prevented by treating the water supply with UV light. (*Contact: T. Evelyn.*)

Vaccination of Pacific salmon by injection.

Fish Disease Control Activities

Disease diagnostic and control activities were performed in relation to SEP facilities and the salmon farming industry. Some major results were:

The Diagnostic Service assisted growers in development of a broodstock screening program to help combat BKD. The objective was to break the causative bacterium's mode of vertical transmission, but detection of the organism in lightly infected adults has been more difficult than anticipated. (*Contact: G. Hoskins.*)

To minimize BKD in the absence of effective vaccines and chemotherapy, selection of hatchery management and rearing techniques is critical. Assistance to fish farmers has been provided through on-site meetings to discuss possible remedial actions in terms of management and rearing. (*Contact: G. Hoskins.*)

The rapid growth of the aquaculture industry has resulted in a demand for trained, skilled fish culturists. DFO has assisted by providing training through laboratory sessions at the Pacific Biological Station and with on-site seminars on disease prevention and control procedures. (*Contact: G. Hoskins.*)

A number of trout farms were certified for export of fish under the Canadian Fish Health Protection Regulations.

To prevent introduction of "exotic" diseases to B.C., quarantine facilities and procedures were designed for holding Atlantic salmon eggs imported from Scotland by commercial salmon farmers. The quarantined fish were closely monitored for infectious disease agents. No exotic diseases were found in the imported stocks and the fish have been surprisingly free of health problems while under quarantine. However, following their release from quarantine and subsequent introduction to sea water, a few groups have contracted BKD. *(Contact: G. Hoskins.)*

Guidelines and policies were developed to reduce the risk of disease transmission from fish farms to SEP facilities, the introduction of exotic fish pathogens into British Columbia and the spread of diseases within B.C. (*Contact: G. Hoskins.*)

While major mortalities in SEP hatcheries were generally avoided through application of disease control procedures and good management practices, there were a few exceptions. A warm water bacterium, *Edwardsiella tarda*, known to cause losses among cultured catfish, was isolated for the first time from ailing and moribund coho fry at one hatchery. This finding reflects the water quality and temperature problems at the hatchery. A common water and sewage organism, *Pseudomonas putrefaciens*, was found to be the cause of heavy mortalities among cultured chinook in another hatchery. Contamination of the facility's water supply may have been responsible. (*Contact: G. Hoskins.*)

Shellfish Diseases

The investigation of shellfish diseases is a new activity for PBS researchers. Activities have included the investigation of the summer mortality of mussels, a perennial problem. Although a neoplastic condition was encountered frequently, this was not considered to be the cause of these mortalities. In addition, a promising immunofluorescent technique was developed for detecting early stages in a parasitic disease of cultured abalone, which may lead to early treatment to prevent mortalities. Clam and oyster surveys were initiated to build a database on the parasites and diseases affecting these shellfish. (*Contact: S. Bower.*)

Parasitology

Principal results in 1986/87 relate to three projects:

Pacific ocean perch stocks were demonstrated to be distinguishable by differences in the occurrence of a parasitic copepod, *Neobrachiella*. These results are particularly significant because the usual methods of tagging cannot be used on this deepwater fish. (*Contact: Z. Kabata.*)

Differences in parasite occurrence showed that seamount populations of sablefish are distinct from continental shelf-dwelling stocks, allowing for separate management of these stocks. (*Contact: Z. Kabata.*)

The protozoan parasite *Ceratomyxa shasta* was not found to be a cause of major mortalities of seaward migrating juvenile chinook salmon in the Fraser River. Only 3% of the migrants sampled in lower regions of the river and the estuary from mid-March to late July were infected, with no infections found prior to early June. (*Contact: L. Margolis.*)

Fish Culture

The section conducts research in a wide range of disciplines related to commercial aquaculture and resource enhancement. Research areas include nutrition, controlled reproduction, biotechnology, genetics, smoltification, environmental influences on growth and development and incubation and water quality. In 1986/87 the section was designated as a Centre of Disciplinary Expertise (CODE) for biotechnology and genetics.

The past year has seen a continued increase in requests for advice of all types from

the growing mariculture industry in British Columbia. These ranged from general enquiries to requests for detailed information and advice on the implementation of specific technologies within production systems. Section staff have also provided data and advice for the Nechako River Court Action. (*Contact: E. M. Donaldson.*)

Nutrition

A study conducted at the Puntledge Hatchery demonstrated that the experimental West Van P-10 dry diet supports growth of juvenile chinook and chum salmon that is equivalent to or better than that of juveniles fed on the traditional Oregon-moist pellet (OMP) semi-moist diet. An experiment with juvenile sablefish demonstrated that silage-based diets have excellent potential for culture of this new candidate for mariculture. Another study demonstrated a clearcut effect of dietary lipid oxidation on performance of juvenile coho salmon. Postdoctoral fellow Bob Roy completed a study which demonstrated significant effects of the fatty acid composition of dietary lipids on the performance of chinook salmon broodstock. Another experiment showed that the West Van P-10 dry diet supports growth of accelerated coho salmon both in fresh and in salt water at least as well as the semi-moist Biodiet.

The first B.C. Fish Nutrition Mariculture Workshop was organized for the benefit of salmon farmers, fish food manufacturers, representatives of the B.C. fishing industry and research workers from the public and private sectors. (*Contact: D.A. Higgs.*)

Controlled Reproduction

Work continued on the development of sex control methodology for salmon farming. An experiment at the Rosewall Creek Hatchery demonstrated the successful sterilization of chinook salmon through the use of methyltestosterone treatment. An experimental study certificate was obtained from the Department of Health and Welfare to conduct pilot trials using this sterilization procedure in commercial mariculture facilities. Seventeen farms are participating in these studies during the current production cycle. Analysis of sex steroid hormone levels in sterile and normal coho salmon at the time of harvest indicated that the sterile fish have about 1/300th the normal level of these hormones. This data will be used in the registration of procedures for hormonal sterilization.

Female chinook milt was provided to commercial salmon farms for production of all-female offspring. This technique enables industry to eliminate the problem of early maturation of male salmon. Development of female milt for coho salmon is continuing.

Experiments conducted in collaboration with the Sablefish Culture Program resulted

in the first successful induction of ovulation of sablefish which produced viable eggs. This is a very significant step in the development of culture methods for this species. Further details of this program are to be found in the Groundfish section of this report.

A test fishery was conducted on the west coast of Vancouver Island to evaluate the condition of partially sterilized chum salmon.

Assistance was provided to the Chilliwack and Kitimat hatcheries to induce spawning in steelhead trout and chinook salmon. (*Contact: I. Solar.*)

Salmon Genetics

A genetic evaluation of four strains of coho salmon was completed, providing strong evidence for the presence of substantial genetic variation among and within strains for traits of commercial importance. Juvenile weight, adult weight, levels of precocious maturation and flesh colour all varied among and/or within strains. This indicates that a judicious choice of wild strain or strains, coupled with a selective breeding program, could lead to the development of a domesticated coho salmon brood stock with superior performance traits for netpen culture conditions.

As part of an experimental selection for size project at the Quinsam Hatchery, returning adults were recovered and second generation crosses on selected and control lines were carried out.

A laboratory experiment on sperm competition demonstrated that not all males represented in a pooled milt sample contribute equally to fertilization. This indicates that the hatchery practice of pooling milt may reduce genetic variation to a greater extent than previously realized.

Analysis of the alevin mortality syndrome at the Chehalis Hatchery revealed a genetic influence on the mortality. (*Contact: R. Withler.*)

Chinook Broodstock Strain Comparison

The study began in 1985 with the delivery of marked families of chinook salmon smolts to four commercial salmon farms and the PBS fish farm. In 1986/87, sampling indicated that growth and survival differed significantly among stocks and among rearing sites. Feed conversion efficiency also varied considerably with site and stock. The incidence of jacks (two-year old precocious males) differed by a factor of three among sites and by a factor of 12 by stock. Overall, growth performance was

better than in previous experiments due to use of an improved diet. (*Contact: H. Kreiberg.*)

Three kilogram Kalum River chinook after two years in sea pen culture.

Salmonid Mariculture

Laboratory experiments demonstrated the feasibility of using a constant short daylength for two months from the time of first feeding to accelerate smolting in coho and stream-type chinook salmon. Atlantic salmon smolts were transferred to net pens to evaluate the performance of this new mariculture species. Results during the first year in the seapens indicate that Atlantic salmon are much more sensitive to blooms of the diatom *Chaetoceros convolutus* than are coho and chinook salmon. This may limit considerably the number of potential sites where Atlantic salmon can be grown successfully. Pilot scale experiments indicated that hormonally sterilized and triploid coho have growth rates comparable to normal coho during the first 12 months in the sea. Experiments with chinook smolts demonstrated the beneficial effects of light sedation and brackish water on survival during transport. A

workshop on coho rearing strategies was conducted for salmon farmers. (*Contact: C. Clarke.*)

Netpens at PBS Fish Farm, Departure Bay.

Biotechnology

Research into chromosome set manipulation of salmonids continued with the evaluation of growth and survival of triploid coho salmon at commercial salmon farms. A commercial scale pressure shocking device used to induce triploidy was field tested, and proved to be very effective. Reproductive physiology of triploid rainbow trout and Pacific salmon was compared with that of normal diploids through measurement of plasma levels of gonadotropin, sex steroids and vitellogenin, and the development of gonads and secondary sexual characteristics. Triploid females were found to be completely sterile, whereas, triploid males appeared to mature. By means of hormonal manipulation, all-female triploid coho and chinook salmon were produced for evaluation as sterile fish for aquaculture. As well, gynogenetic diploid coho salmon were hormonally masculinized to provide female milt. A

preliminary triploid hybridization study using coho and sockeye salmon was undertaken at the Cultus Lake Laboratory.

Studies of hormonal acceleration of growth in Pacific salmon continued with the testing of novel recombinant peptides and monoclonal antibodies to somatostatin. The monoclonal antibody showed promising growth promoting properties in a preliminary study conducted on yearling coho salmon. A recently developed analog of recombinant bovine somatotropin had approximately nine times the potency of native bovine somatotropin. The uptake and clearance rates of recombinant somatotropin from plasma were measured in coho salmon given slow-release implants, and were found to be considerably extended over the clearance of those observed after a single injection. Growth of chinook salmon in seawater was considerably enhanced with continuous infusion of recombinant somatotropin. The effect of temperature on the response to somatotropin injection was studied in juvenile Atlantic salmon. The effect of somatotropin on growth during saltwater transfer was tested in coho salmon at different sizes. (*Contact: E. Donaldson.*)

Incubation and Water Quality

Incubation of sablefish eggs has been investigated as part of a larger collaborative project on sablefish culture. Egg and sperm collection, storage and transport, fertilization and incubation techniques have been tested. The results from these tests have been employed to yield high fertilization (85-90%) and subsequent survival to hatching of 24%. To achieve the current levels of survival, great care must be taken in handling the extremely fragile eggs. In addition, a unique incubation system, employing rotating cylindrical containers, has been developed. Tests are continuing to further improve egg and larval survival. (*Contact: J. Jensen.*)

Studies of the alevin mortality syndrome at Chehalis Hatchery were completed, demonstrating that addition of sodium and calcium salts to the water improved survival.

Preliminary experiments on moist air incubation of coho salmon eggs provided information which will be used in the development of apparatus for larger tests next year.

An expert report on the effects of total gas pressure was submitted to the Nechako Task Force. (*Contact: J. Jensen.*)

Time and Size

Recoveries of tagged steelhead returning to Rosewall Creek indicated the optimum

release date for smolts is in late April. Returns of two-sea-winter fish were greater from release of large smolts. Preliminary analysis of the return data shows no obvious effects of parental age on return rate or age at maturity.

Tagged chinook salmon were recovered at the Quinsam Hatchery from releases made in 1982 and 1983. Preliminary results indicated that release of large smolts in early May produce greatest returns of adult salmon. Final returns from these experiments are expected in 1988.

Data analysis was completed from three time-and-size-at-release experiments for coho salmon at Quinsam River Hatchery. Results for all three years were very consistent, showing a marked effect of release date on adult return while smolt size at release had only very minor effects. (*Contact: B. Morley.*)

Stress and Histopathology

In a laboratory experiment assessing the efficacy of incorporating 17-methyl-testosterone (10 ppm) in the diet for 12 weeks to sterilize juvenile coho, it was observed that all treated fish, male and female, were sterilized, there were no deleterious structural changes noted in the liver or kidney of the treated fish, and that the marked thickening in the skin epithelial layer of the treated fish (approx. 300%) was reversed following withdrawal of the hormone. (*Contact: J.R. McBride.*)

Habitat Capacity

Research conducted in this section determines the fish productivity of fresh water, estuarine and marine habitats for stock and habitat management. Research data are provided on the impact of industrial activity, including forestry, transportation, wastewater discharge, hydroelectric, agricultural sectors and on the capacity of the regional habitat base to produce fish. Research projects are conducted to define the utilization of habitats by fish and the dependence of fish stocks on specific habitat types.

Fraser River Capacity Program

The primary objective of the Fraser River program is to provide better understanding of how habitat factors, including man's activities, affect the capacity of the drainage

basin to produce salmon. The basin supports some of the most important stocks of salmon in the region.

Results from ecological studies in the Nicola sub-basin, a southern tributary, showed that off-channel habitats are particularly important for the rearing of coho. Winter ice conditions in the main river are severe and juvenile coho are adapted to use groundwater-fed habitats, such as beaver ponds. Evidence now indicates the ponds may be important for summer rearing as well. Data from this study were used in designing coho habitat in a compensation program related to construction of the Coquihalla Highway.

Chinook juveniles have also been found in off-channel habitat, but their main overwintering habitat in the mainstem rivers appears to be cobble substrate and, in some instances, riprap. Overwintering chinook populations were sampled in the Nicola River, the Thompson River near the Nicola confluence and the mainstem Fraser. Juvenile chinook were found to be migrating almost all year round, indicating considerable movement between habitats at times when stable residency was previously assumed. (*Contact: C. Levings.*)

Scientists dealing with flow effects provided major assistance to the DFO task force dealing with the Alcan court case regarding the Nechako River water flows. Over 5000 pages of documents were reviewed, extensive expert reports were prepared and guidance to Department of Justice staff was given. In addition, several major contracts dealing with hydrology of the Nechako River were supervised. Over 25 km of river were surveyed in late summer to determine microhabitat preferences of the juvenile chinook. (*Contact: C. Shirvell.*)

Pollution-toxicology research involved studies to evaluate sublethal effects of contaminants in the Fraser River and possible bioaccumulation. A field program to investigate uptake of organic contaminants by eulachon as they migrated upriver through the estuary was conducted in May. Preliminary assessments of the data reveal the uptake of organic contaminants during the migration. Fish collected from the upriver sampling location contained greater concentrations than those fish collected at the river mouth. These anadromous fish are considered to be good candidates for biomonitoring for organic contaminants because of their high lipid content. Laboratory studies emphasized further development of the water column simulator (WCS) at the West Vancouver Laboratory. The simulator provides vertical stratification for temperature, salinity and dissolved oxygen, enabling behavioural observations of juvenile salmon under a range of habitat conditions, including those found in polluted estuaries. Under simulated estuarine conditions juvenile chinook salmon consistently avoided dissolved oxygen levels at and below about 7 mgL^{-1} in surface fresh water, by moving into deeper salt water. Transient excursions of these fish into surface waters containing lethal and sub-optimal levels of dissolved oxygen implies that degraded habitats will be utilized due to inate behavioural traits. Recent developments have included the acquisition of image analysis equipment to facilitate the quantification of fish positions in the WCS and the installation of better temperature control facilities to permit year-round use. (*Contact: I. Birtwell.*)

A study was conducted to document bioaccumulation of chlorophenols in pink

salmon (*Oncorhynchus gorbuscha*) from the egg to fry stage. The study included exposure of pink salmon at egg to fry stage to sub-lethal amounts of Woodbrite in Fraser River water at the Cultus Lake Laboratory. Feral emergent pink salmon fry were captured for chlorophenol analyses from spawning beds in the Fraser River near Chilliwack, tributaries to the Fraser River and from the Thompson River. Results demonstrated bioaccumulation of chlorophenols in both the long-term laboratory exposure and the natural environment. There were indications that chlorophenols had a negative effect on energy reserves of pink salmon in the laboratory tests.

The Fraser River and some tributaries carry variable suspended sediment loads. To assist managers understand the implications of various types and concentrations of suspended sediments, studies were begun in 1983 at Cultus Lake Laboratory. These studies showed that lethality of Fraser River suspended sediments to juvenile sockeye salmon was a function of particle size, that smolts suffered a slight impairment of hypo-osmoregulatory capacity following exposure to a near lethal concentration of suspended sediment and that adult sockeye had significantly elevated plasma glucose levels following exposure to suspended sediment concentrations which have been recorded in the Fraser River during spawning migrations.

More recently, tests have revealed that the 96hLC50 for juvenile coho (*O. kisutch*) and chinook salmon (*O. tshawytscha*) exposed to Fraser River suspended sediments was temperature dependent; 96hLC50 rose as temperature decreased from 18°C to 6°C. Data have also indicated avoidance by juvenile coho of suspended sediments over the range 140 to 16,000 mgL^{-1}. Analysis by electron microscopy indicated that particles of suspended sediments were phagocytosed by gills of juvenile sockeye, coho and chinook. (*Contact: J. Servizi.*)

Fish-Forestry Program

The fish-forestry program in 1986/87 consisted of two major research projects, both involving extensive collaboration with the forest industry.

The Carnation Creek project began in 1970 and was envisaged to continue for 15 years. Much of the field work was completed by December 1985 and extensive data analyses and reporting were done in 1986. Results showed that coho grew faster after logging, primarily due to increased winter temperatures because of canopy opening. However the survival benefits of this growth increment may have been obviated because seaward migration of smolts was advanced to sub-optimal conditions. A decision was made to continue monitoring for a further two years certain key elements of the project that were particularly relevant to coho population dynamics. These elements included fry enumerations, smolt outmigrations, adult returns and temperature data. There was a restructuring of camp operations, and costs are now distributed among the various groups using the Carnation Creek facilities for research. In addition to DFO's Biological Sciences and Fisheries

Branches, these include B.C. Ministry of Forests, B.C. Ministry of Environment and Parks, Canadian Forest Service, Environment Canada and the Council of Forest Industries. Analyses of samples collected from a study concerned with the effects of the herbicide Roundup continued. This herbicide was applied to a portion of the Carnation Creek watershed in September 1984. Financial support for this project has been provided by the Forest Pest Management Institute at Sault St. Marie (Canadian Forest Service). (*Contact: C. Scrivener.*)

In 1986, preliminary work began on a new synoptic Fish-Forestry program which expanded work into other drainage basins. The objective of the work is to test certain hypotheses generated at Carnation Creek on other watersheds. A major world literature review was conducted on synoptic fish-forestry research and over 1600 references were compiled. Assembly of a data base on the logging history and fish populations on approximately 35 streams on the west coast of Vancouver Island began. Planning for aerial photography and associated ground truthing of these streams was also conducted and contacts were established with forest companies. (*Contact: I. Williams.*)

Coastal Habitat Program

Field research at the Campbell River estuary was executed as planned to evaluate the significance of estuarine habitat restoration. Results showed that juvenile chum and chinook used the man-made islands more extensively than in any of the previous years. Salmon food supplies on the islands were also evaluated in a cooperative project with B.C. Forest Products Ltd. and invertebrate sampling indicated crustacean and insect communities were merging with reference habitats. Marked adult chinook from experimental releases in 1983, 1984 and 1985 were recovered from the Campbell River system in a cooperative program with SEP. Adult returns and contributions to the fishery were highest from groups released to the river and estuary. Extensive data analyses and statistical exploration of microhabitat information were conducted. In addition, scientists provided major review and comments pertaining to possible biological effects of offshore oil drilling on the north coast of B.C. and provided advice on other estuarine and foreshore habitat issues in the region. (*Contact: C. McAllister.*)

Science and Survey Support

Ships

Ship Division provided ship, submersible, launch and depot support for the science and hydrographic programs of the Institute of Ocean Sciences, the fisheries research conducted from the Pacific Biological Station and its satellites, other federal agencies and universities. During the latter part of the fiscal year considerable reorganization took place, including consolidation of regional ships' management staff at IOS, in readiness for the amalgamation of the science, survey and enforcement fleets which took place on April 1, 1987.

In June 1986, the FRV G.B. REED was phased out of government service. Named after Dr. G.B. Reed, chairman of the Fisheries Research Board of Canada from 1947-1953, the REED was the first ship built specifically for fisheries research work in the Pacific Region. In her 24 years as the Pacific Biological Station's primary research vessel, the G.B. REED played an integral role in a wide variety of scientific investigations. Launched in 1962 at Yarrow Shipyards in Victoria, the ship's major activity until the mid-1970s was as a research platform for studies to determine the high seas distribution of North American and Asian salmon. With the extension of Canada's fisheries jurisdiction in 1977, groundfish studies became a major focus and again the G.B. REED was an essential participant.

FRV CALIGUS (home port, PBS; 17 metres overall; gross tonnage 41.36)

The multi-purpose FRV CALIGUS spent 202 operational days in 1986/87 steaming over 5,000 nautical miles. The year was spent in coastal B.C. waters on a variety of tasks, including shellfish, groundfish and salmon research and participating in current surveys. In the spring of 1987, the CALIGUS participated in the herring roe fishery as a sampling platform.

CSS PARIZEAU (home port, IOS; 64.3 metres overall; gross tonnage 1314)

In the early part of 1986/87 the PARIZEAU provided support to Ocean Physics, Ocean Ecology and Tides and Currents for IOS. The 22,000 miles steamed over 174 days also included work for PBS, Pacific Geoscience Centre and Defence Research Establishment, Pacific. Later, she commenced refit and conversion to Unmanned Machinery Space configuration.

Fisheries Research Vessel W.E. RICKER on sea trials in June 1986 in English Bay.

CSS RICHARDSON (home port,IOS; 19.8 metres overall; gross tonnage 59)

The CSS RICHARDSON spent the major part of the year engaged in hydrographic survey work in Cumshewa Inlet. In March of 1987 she assumed Search and Rescue (SAR) duties with the herring fleet.

FRV W.E. RICKER (home port, PBS; 58 metres overall; gross tonnage 1105.52)

The G.B. REED's replacement, the FRV W.E. RICKER is a converted commercial freezer trawler. The RICKER's stern trawler design facilitates the use of state of the art gear for bottom and mid-water trawling as well as the deployment of other scientific gear. Her open deck arrangement allows for easy conversion to other fishing methods. The ship carries a crew of 24 and has accommodations for up to 12 scientific staff. She is named in honour of eminent fisheries scientist, Dr. W.E. Ricker who was recently appointed to the Order of Canada in recognition of his outstanding contribution to fisheries science. The foreign going vessel will continue both the high seas research and coastal work started by the G.B. REED.

The FRV W.E. RICKER was commissioned into government service on May 24, 1986. Over the 1986/87 year she covered over 10,000 nautical miles in a total of 156 operational days. Her first major activity was a squid research cruise from August 19 to September 12 conducted on the Pacific high seas. Other groundfish research

cruises followed and in February/March 1987, the RICKER served as both a research and management vessel for the herring roe fishery. The year wrapped up with an offshore black cod research cruise.

CSS JOHN P. TULLY (home port, IOS; 69 metres overall; gross tonnage 2199)

JOHN P. TULLY covered 19,200 miles over 177 days in 1986/87 with the major cruise being a continuation of the Beaufort Sea hydrographic survey, involving both IOS hydrographic staff and the Atlantic Geoscience Centre. The TULLY left for the Arctic in early July and returned in October. The ship also visited Expo 86 in May for two weeks to participate in the World Fair opening ceremonies and the Polar Transportation and Communications Specialized Period. The TULLY substituted for the CSS PARIZEAU undertaking SAR duties during the herring roe fishery.

CSS VECTOR (home port, IOS; 39.6 metres overall; gross tonnage 516)

VECTOR provided support to scientists from IOS (Ocean Physics, Ocean Chemistry and Tides and Currents), UBC, Simon Fraser University, University of Victoria, EPS and PGC. Miles totalled 11,000 over 147 days.

Submersible PISCES IV (home port, IOS; 6.1 metres overall; gross tonnage 12)

The PISCES IV completed over 130 dives in support of scientific programs with NOAA, University of Victoria, B.C. Provincial Museum, Bamfield Marine Station, PBS, UBC, PGC and IOS. She also visited the Underwater and Offshore Resources Specialized Period at Expo 86 and personnel took part in ROV training. Work was also undertaken in Everett, Washington.

Barges PENDER and L. PACIFICA (home port, IOS)

The PENDER spent most of the year acting as mothership to the submersible, PISCES IV. This involved tows to Barkley Sound, Jervis Inlet and Everett, Washington.

The L. PACIFICA, originally a PBS survey platform, was modified by depot personnel as living quarters for hydrographic or other field parties. In mid-May she was towed to Clayoquot Sound for hydrography use, returning to Patricia Bay in mid-October.

Deck Machinery

The Deck Machinery staff continued to provide maintenance and upgrading of winches, cranes, etc. Due to problems with the davits on the CSS JOHN P. TULLY considerable time was spent rebuilding three sets, leaving one set to be rebuilt at a future date.

Depot Workshops

The depot workshops had an extremely busy year providing support for the JOHN P. TULLY Arctic survey, the barges PENDER and L. PACIFICA and to RICHARDSON hydrographic survey in the Queen Charlottes. In addition, the depot responded to 75 other branch requests and over 1,700 in-house work requests. The final two Houston launches arrived, bringing the total to six.

A computerized management and information system was developed and implemented to improve productivity and to prepare for workload increases as a result of Ship Division consolidation at IOS.

Computing

During 1986/87 computing staff from PBS and IOS were involved in developing a regional long-range capital acquisition plan and in an organizational review; the latter resulting in the establishment of a regional EDP co-ordinator in Vancouver, a Science EDP co-ordinator at IOS and a Biological Sciences EDP co-ordinator at PBS. Within DFO Science, Pacific Region computer analyst and programmer support is integral to virtually all aspects of science and survey data collection, transmission and analysis.

At IOS, the most significant activity in the past year was the acquisition of a VAX-11/785 for the central computer facility. The new system includes a 16 Mb memory, 1.3 Gb disk storage, two tape drives, three line printers, one laser printer, and 24 terminal lines. Installed software includes various productivity aids such as a full screen editor and a comprehensive graphics package (DISSPLA). Cabling was also installed for a high-speed, on-site communications network to link VAX computers using the Ethernet system.

With Fall 1987 set for termination of most applications on the mainframe Sperry computer, conversions accelerated throughout the year and training courses on the VAX and DISSPLA were conducted.

The trend towards the use of micro-computers for data acquisition, preliminary data processing and personal productivity (word processing, spread sheets, small databases) continued with the acquisition of 15 more personal systems. At the other end of the scale, use of the Cray super-computers at AES, Dorval for ocean modelling doubled to 85 Cray-1S equivalent hours in 1986/87.

A central computer facility workload analysis revealed that compute-intensive numerical modelling was the fastest growing application and recommended a significant upgrade. A "compute server", in the form of a mini-supercomputer or attached processor linked to the VAX, was proposed. *(Contact: K. Teng.)*

The Biological Sciences VAX 11/780 at PBS was primarily used for stock and composition assessment data analysis, numerical modelling and statistical analysis. Interactive use totalled approximately 47,000 hours and batch use accounted for 21,000 hours.

To alleviate the overload situation on the VAX 11/780, a Microvax II was installed primarily to support stock assessment activities and to handle numerical modelling, and software development related to the mark recovery program. A Vax 730 was also installed on the FRV W.E. RICKER.

A software package, Maple, was acquired for symbolic computation and for verification of computer models involving calculus.

Work was also undertaken developing data and database standards for international salmon data exchange, specifically related to the Canada/U.S. Pacific Salmon Treaty. (*Contact: S. McKinnell.*)

Communications

1986/87 was an eventful year for communications in the Science Sector, Pacific Region. Activities included major special events, on-going projects and the more routine requests and queries for information from the general public and a variety of client groups.

The Pacific Biological Station decked out for Open House.

The newest addition to the research fleet, the FRV W. E. RICKER was commissioned in May in Vancouver and later welcomed to the Pacific Biological Station by Dr. Ricker, research staff and local officials.

A very successful Open House was held at the Pacific Biological Station in September. Over 11,000 visitors took advantage of the opportunity to tour the facility and the W.E. RICKER and participate in a variety of "hands-on" exhibits, computer demonstrations and other activities over a five day period.

School children getting acquainted with a tankful of lamprey.

Expo 86 invited the CSS JOHN P. TULLY to participate in the opening ceremonies in May. The ship was also open to the public and special interest groups during the Arctic Transportation and Communications Specialized Period. A display in the main laboratory highlighted Arctic research and hydrography. The submersible PISCES IV also took part in the final Specialized Period of the World Fair; this one featuring Underwater and Offshore Resources.

As part of on-going tour programs, both the Pacific Biological Station and the Institute of Ocean Sciences continued to attract large numbers of visitors, including

school groups, tourists, service clubs and members of the general public. At IOS, over 2000 people toured the facility during the year.

Also completed during the year was an IOS Annual Review of Activities, a new PBS brochure, submissions to a variety of publications and a number of Aquaculture Update fact sheets published specifically for the industry. (*Contact: K. Francis, PBS; K. Glover, IOS.*)

Management Services Branch/ Comptroller's Branch

Administrative and Financial services at IOS and PBS were re-organized into the overall DFO regional structure in conjunction with science integration.

Administrative support, including facilities management, telecommunications, records management, materiel management, ship operations and library services are provided by Management Services Branch. Financial analysis and control is provided by the Comptroller's Branch.

During the past year, some systems were integrated with those of other units in the region. Included in the workload increase as a result of re-organization was the establishment of the regional marine depot at IOS to provide ships' management for the science, survey and enforcement vessels of the region.

A two-year, CEIC-sponsored job development program came to an end in March 1987 with IOS Management Services acting as the facilitator for the placement of young people with private companies and government operations in science and technology related activities.

Construction of new facilities at the West Vancouver Laboratory involved Management Services staff in monitoring construction activities, and ensuring that scientific, mechanical and electrical needs were addressed. (*Contact: W.B. Ross, PBS; J. Coldwell, IOS.*)

Appendix I

Publications 1986/87

Institute of Ocean Sciences

Anderson, E. P., and D. L. Mackas. 1986. Lethal and sublethal effects of a molybdenum mine tailing on marine zooplankton: mortality, respiration, feeding and swimming behavior in *Calanus marshallae, Metridia pacifica* and *Euphausia pacifica*. *Mar. Envir. Res.* 19:131-155.

Armi, L., and D. M. Farmer. 1986. Maximal two-layer exchange through a contraction with barotropic net flow. *J. Fluid Mech.* 164:27-51.

Bennett, A. F. 1986. High wavenumber spectrum of a passive scalar in isotropic turbulence. *Phys. Fluids* 29(5):1734-1735.

Bennett, A. F. 1986. Random walks with manholes: simple models of dispersion in turbulence with coherent vortices. *J. Geophys. Res.* 91(C9):10769-10770.

Bennett, A. F., and W. B. White. 1986. Eddy heat flux in the subtropical North Pacific. *J. Phys. Oceanogr.* 16(4):728-740.

Borstad, G. A., J. F. R. Gower, and D. N. Truax. 1986. Analysis of data from the DFO fluorescence line imager. In *Proc. 10th Canadian Symposium on Remote Sensing, Edmonton, Alberta, May 5-8, 1986*, 413-422. Canadian Aeronautics and Space Institute, Ottawa.

Brinkhurst, R. O. 1986. Taxonomy of the genus Tubificoides Lastockin (Oligochaeta, Tubificidae): species with bifid chaetae. *J. Zool.* 64:1270-1279.

Brinkhurst, R. O. 1986. Report, Working Group 9. In *Toward A Transboundary Monitoring Network*, ed. P. T. Haug, B. L. Bandursky and A. L. Hamilton, Vol. 1, 261-63. International Joint Commission, U.S. and Canada, Washington, D.C.

Brinkhurst, R. O. 1986. *Guide to the Freshwater Aquatic Microdrile Oligochaetes of North America*. Can. Special Publ. Fish. Aquat. Sci. 84:1-259.

Brinkhurst, R. O. 1986. *The Ocean Ecology Division, Institute of Ocean Sciences: the First Decade, 1976-86*. Can. Tech. Rep. Hydrog. Ocean Sci. No. 72:24 p.

Brinkhurst, R. O. 1986. The three-fold path (modified version). In *Report on Ocean Dumping R&D Pacific Region 1986-87*, ed. S. M. Woods. Can. Contr. Rep. Hydrog. Ocean Sci. No. 26:1-43.

Budgell, W. P. 1986. Nonlinear data assimilation for shallow water equations in branched channels. *J. Geophys. Res.* 91(C9):10,633-10,644.

Carmack, E. 1986. Circulation and mixing in ice-covered waters. In *The Geophysics of Sea Ice*, ed. N. Untersteiner. Plenum Publishing Corporation. pp. 641-712.

Carmack, E., R. Wiegand, C. Gray, R. Daley, C. Pharo, and S. Jasper. 1986. Mechanisms influencing the circulation and distribution of water masses in a medium residence-time lake. *Limnology and Oceanography* 31:249-265.

Chapman, P. M., and R. O. Brinkhurst. 1986. Setal morphology of the oligochaetes *Tubifex tubifex* and *Ilyodrilus frantzi* (capillatus) as revealed by SEM. *Proc. Biol. Soc. Wash.* 99(2):323-327.

Cherniawsky, J. Y., J. F. R. Gower, H. Melling, D. N. Truax, and R. C. Kerr. 1986. Using NOAA AVHRR imagery in studies of sea ice motion in the Beaufort Sea. In *Proc. 10th Canadian Symposium on Remote Sensing, Edmonton, Alberta, May 5-8, 1986*, 395-403. Canadian Aeronautics and Space Institute, Ottawa.

Church, J. A., H. J. Freeland, and R. L. Smith. 1986. Coastal-trapped waves on the east Australian continental shelf. Part I: Propagation of modes. *J. Phys. Oceanogr.* 16(11):1929-1943.

Church, J. A., N. J. White, A. J. Clarke, H. J. Freeland, and R. L. Smith. 1986. Coastal-trapped waves on the east Australian continental shelf. Part II: Model verification. *J. Phys. Oceanogr.* 16(11):1945-1957.

Crawford, W. R. 1986. A comparison of length scales and decay times of turbulence in stably stratified flows. *J. Phys. Oceanogr.* 16(11):1847-1854.

Crawford, W. R., W. S. Huggett, M. J. Woodward, and P. Daniel. 1985. Summer circulation of the waters in Queen Charlotte Sound. *Atmosphere-Ocean* 23:393-413.

Crowther, W. S. et al. 1986. The making of an atlas for the recreational boater. In *Proc. Canadian Hydrographic Conference, Burlington, Ontario, February, 1987.*

Denman, K. L., and J. Marra. 1986. Modelling the time dependent photoadaptation of phytoplankton to fluctuating light. In *Marine Interfaces Ecohydrodynamics*, ed. J. C. J. Nihoul, 341-59. Elsevier, Amsterdam.

Druffel, E. R. M., S. Honjo, S. Griffin, and C. S. Wong. 1986. Radiocarbon in particulate matter from the eastern sub-arctic, Pacific Ocean: Evidence of a source of terrestrial carbon to the deep sea. *Radiocarbon* 28(2A):397-407.

El-Sabh, M. I., and T. S. Murty. 1986. Seasonal and long-term sea level variations in the Atlantic coast of Canada. *Marine Geodesy* 10(3-4).

El-Sabh, M. I., and T. S. Murty. 1986. Numerical modelling of tsunami generation and propagation in the St. Lawrence estuary, Canada. *Modelling Simulation and Control* C4(4):49-64.

Emery, W. J., A. C. Thomas, M. J. Collins, W. R. Crawford, and D. L. Mackas. 1986. An objective method for computing advective surface velocities from sequential infrared satellite images. *J. Geophys. Res.* 91(C11):12,865-12,878.

Emery, W. J., A. C. Thomas, M. J. Collins, W. R. Crawford, and D. L. Mackas. 1986. Comparison between satellite image advective velocities, dynamic topography and surface drifter trajectories. *EOS* 67(22):498-499.

Farmer, D. M., and L. Armi. 1986. Maximal two-layer exchange over a sill and through the combination of a sill and contraction with barotropic flow. *J. Fluid Mech.* 164:53-76.

Farmer, D. M., and S. F. Clifford. 1986. Space-time acoustic scintillation analysis: A new technique for probing ocean flows. *Oceanic Engineering* 11(1):42-50.

Flegal, A. R., K. Itoh, C. C. Patterson, and C. S. Wong. 1986. Vertical profile of lead isotopic compositions in the north-east Pacific. *Nature* 321:689-690.

Forbes, J. R., K. L. Denman, and D. L. Mackas. 1986. Determinations of photosynthetic capacity in coastal marine phytoplankton effects of assay irradiance and variability of photosynthetic parameters. *Mar. Ecol. Prog. Ser.* 32:181-191.

Foreman, M. G. G. 1986. An accuracy analysis of boundary conditions for the forced shallow water equations. *J. Comput. Phys.* 64(2):334-367.

Freeland, H. J., F. M. Boland, J. A. Church, A. J. Clarke, A. M. G. Forbes, A. Huyer, R. L. Smith, R. O. R. Y. Thompson, and N. J. White. 1986. The Australian coastal experiment: A search for coastal-trapped waves. *J. Phys. Oceanogr.* 16(7):1230-1249.

Galloway, J. L., S. Jarvin, and J. Mattock. 1986. A correlation sonar system for recording ice cover movement. In *Proc. of Oceans 86*, IEEE.

Gargett, A. E. 1986. Small-scale parameterization in large-scale ocean models. In *Advanced Physical Oceanographic Numerical Modelling*, ed. J.J. O'Brien, 145-54. Reidel.

Gargett, A. E., G. Ostlund, and C. S. Wong. 1986. Tritium time series from Ocean Station P. *J. Phys. Oceanogr.* 16(10):1720-1726.

Gower, J.F.R., G.A. Borstad, and A.B. Hollinger. 1986. Development of an imaging optical spectrometer for ocean and land remote sensing. In *Proc. Int. Symposium on the Spectral Signatures of Objects in Remote Sensing, Les Arcs, France, Dec. 16-20*, 219-25. ESA SP-247.

Gower, J. F. R., J. Y. Cherniawsky, and G. A. Borstad. 1986. Motion of ice in the Beaufort Sea from satellite and aircraft images. In *Proc. Canadian East Coast Workshop on Sea Ice, B10, January 7-9.* Can. Tech. Rep. Hydrog. Ocean. Sci. No. 73.

Greisman, P. 1986. *Surface Circulation in Dixon Entrance Results from Lagrangian and Eulerian Measurements.* Can. Contr. Rep. Hydrog. Ocean Sci. No. 23.

Harwood, L. A., L. A. Turney, L. de March, B. D. Smiley, and P. Norton. 1986. *Arctic Data Compilation and Appraisal, Beaufort Sea: Biological Oceanography - Seals, 1826-1985.* Can. Data Rep. Hydrog. Ocean Sci. No. 5:Vol. 8, Part 1, 352 p.; Part 2, 301 p.

Herlinveaux, R. H., F. A. Whitney, and J. A. McFarlane. 1986. *Investigation of Fish Kills in Active Pass, B.C. in May 1983.* Can. Data Rep. Hydrog. Ocean Sci. No. 47.

Holloway, G. 1986. Eddies, waves, circulation and mixing: statistical geofluid mechanics. *Annual Review Fluid Mechanics* 18:81-147.

Holloway, G. 1986. Estimation of oceanic eddy transports from satellite altimetry. *Nature* 323:243-244.

Holloway, G. 1986. A shelf wave/topographic pump drives mean coastal circulation. *Ocean Modelling*, Nos. 68 and 69.

Holloway, G. 1986. Comments on Fofonoff's mode. *Geophys. Astrophys. Fluid Dyn.* 37:165-169.

Holloway, G. 1986. Do turbulence dissipation measurements imply ocean mixing? *Ocean Modelling* No. 70.

Holloway, G., T. S. Murty, and E. Fok. 1986. Effects of bathymetric roughness upon tsunami travel time. *Science of Tsunami Hazards* 4(3):165-172.

Holloway, G., D. Ramsden, and S. C. Riser. 1986. Tracer anomaly evolution in the flow field of an isolated eddy. *Dynamics of Atmospheres and Oceans* 10(2):165-184.

Huggett, W. S. 1986. CSS John P. Tully, a hydrographic and geophysical research vessel. *Int. Hydrographic Review* LXIII(2):31-39.

Johnson, W. K., and C. S. Wong. 1986. Studies on storage and behaviour of mercury with nanogram per litre level in sea water. *Acta Oceanologica Sinica*, Vol. 14.

Juniper, S. K., J. A. J. Thompson, and S. E. Calvert. 1986. Accumulation of minerals and trace elements in biogenic mucus at hydrothermal vents. *Deep Sea Res.* 33(3A):339-347.

Juniper, S.K., and R.O. Brinkhurst. 1986. Water-column dark CO_2 fixation and bacterial-mat growth in intermittently anoxic Saanich Inlet, British Columbia. *Mar. Ecol. Prog. Ser.* 33:41-50.

LeBlond, P. H., B. M. Hickey, and R. E. Thomson. 1986. Runoff driven coastal flow off British Columbia. In *The Role of Freshwater Outflow in Coastal Marine Ecosystems*, ed. S. Shreslet, NATO ASI Series, Vol. G7, 309-17. Springer-Verlag, Amsterdam.

Lewis, E. L., and R. G. Perkin. 1986. Ice pumps and their rates. *J. Geophys. Res.* 91(C10):11756-11762.

Li, J., W. K. Johnson, and C. S. Wong. 1986. Atomic absorption determination of 15 minor and major elements in marine and estuary sediment. *Anal. Chem.* (Chinese) 14(6):460-463.

Li, J., W. K. Johnson, and C. S. Wong. 1986. Heavy metals from harbour sediment released into sea water. A laboratory study. *Acta Oceanologica Sinica* (Chinese) 8(3):314-318.

Lu, X., W. K. Johnson, and C. S. Wong. 1986. Seasonal replenishment of mercury in a coastal fjord by its intermittent anoxicity. *Mar. Poll. Bull.* 17(6):263-267.

Lu, X., W. K. Johnson, and C. S. Wong. 1986. Studies on storage and behaviour of mercury with nanogram per litre level in sea water. *Anal. Chem.* (Chinese) 14(2):98-101.

Luternauer, J. L., R. H. Linden, S. J. Westrheim, and R. E. Thomson. 1986. Sedimentology of Amphitrite Bank, A commercially exploited groundfish habitat - southern continental shelf, British Columbia, Canada. *Environ. Geology and Water Sci.* 8:107-121.

Macdonald, R. W., F. A. McLaughlin, and C. S. Wong. 1986. The storage of reactive silicate samples by freezing. *Limnol. Oceanogr.* 31(5):1139-1142.

Mackas, D. L., and E. P. Anderson. 1986. Small-scale zooplankton community variability in a northern British Columbia fjord system. *Estuarine Coastal and Shelf Sci.* 22:115-142.

Mackas, D. L., and K. E. Burns. 1986. Poststarvation feeding and swimming activity in *Calanus pacificus* and *Metridia pacifica*. *Limnol. Oceanogr.* 31(2):383-391.

Moum, J. N., T. R. Osborn, and W. R. Crawford. 1986. Pacific equitorial turbulence: revisited. *J. Phys. Oceanogr.* 16(9):1516-1522.

Muller, P., G. Holloway, F. Henyey, and N. Pomphrey. 1986. Nonlinear interactions among internal gravity waves. *Reviews of Geophysics* 24(3):493-536.

Murty, T. S. 1986. Comment on "Protection of the human race against natural hazards". *Geology* 14(7):633-34.

Murty, T. S. 1986. State of tsunami research. In *Proc. 10th Workshop on Tsunamis, Victoria, Canada, July 29-31, 1985.*

Murty, T. S. 1986. Tsunami travel-time charts, a critical look at the ocean depth data. In *Proc. Pacific Congress on Marine Technology, Honolulu, March 24-28, 1986.*

Murty, T. S. 1986. Physics of storm surges. In *Proc. Regional Cyclone Surge Workshop, Chittagong, Bangladesh, Dec. 14-19, 1985.*

Murty, T. S. 1986. Historical storm surge data for the Bay of Bengal. In *Proc. Regional Cyclone Surge Workshop, Chittagong, Bangladesh, Dec. 14-19, 1985.*

Murty, T. S. 1986. Computer animation of storm surge predictions. *J. Hydraulic Eng.*, A.S.C.E.

Murty, T. S., and M. I. El-Sabh. 1986. A review of the physical oceanographic characteristics of the Inner Gulf of the Kuwait Action Plan Region. In *Proc. UNESCO Workshop on the Indian Ocean, Colombo, July 8-13, 1985.*

Murty, T. S., and M. I. El-Sabh. 1986. Numerical simulation of a tsunami due to a predicted large earthquake in the St. Lawrence Estuary. In *Proc. Int. Tsunami Symp., Victoria, Canada, Aug. 6-9, 1985*, 75-81.

Murty, T. S., and M. I. El-Sabh. 1986. Treatment of free boundaries in numerical computations of long gravity wave problems. In *Proc. 4th Int. Symp. Innovative Numerical Methods in Engineering*, ed. R.P. Shaw, 261-67. Springer-Verlag, Berlin.

Murty, T. S., R. A. Flather, and R. F. Henry. 1986. The storm surge problem in the Bay of Bengal. *Progress in Oceanography* 16:195-233.

Murty, T. S., R. A. Flather, and R. F. Henry. 1986. Mathematical modelling of storm surges in the Bay of Bengal. In *Proc. UNESCO Workshop on the Indian Ocean, Colombo, July 8-13, 1985.*

Murty, T. S., and W. J. Rapatz. 1986. Marine geodetic processes on the Pacific coast of Canada. *Marine Geodesy* 10(3-4):129-140.

Murty, T. S., and W. J. Rapatz (eds.). 1986. In *Proc. International Tsunami Symposium, Victoria, Canada, Aug. 6-9, 1985,* 325 p.

Murty, T. S., and P. B. Crean. 1986. A reconstruction of the tsunami of June 23, 1946 in the Strait of Georgia. In *Proc. Int. Tsunami Symp., Victoria, Canada, Aug. 6-9,* 1985, 121-125.

Murty, T. S., and P. B. Crean, 1986. Numerical simulation of the tsunami of June 23, 1946 in British CoLumbia, Canada. *Science of Tsunami Hazards.*

Murty, T. S., and N. K. Saxena. 1986. Possible tsunami effects in Hawaii and west coast of North America from a predicted large earthquake in the Aleutian Islands. In *Proc. Pacific Congress on Marine Technology, Honolulu, March 24-28, 1986.*

Norton, P., and B. D. Smiley. 1986. *Importance of Yukon Coastal Waters to Bowhead and White Whales.* Can. Contr. Rep. Hydrog. Ocean Sci. No. 24.

Shen, C. Y., and G. Holloway. 1986. A numerical study of the frequency and the energetics of nonlinear internal gravity waves. *J. Geophys. Res.* 91(C1):953-973.

Tabata, S., B. Thomas, and D. Ramsden. 1986. Annual and interannual variability of steric sea level along Line P in the northeast Pacific Ocean. *J. Phys. Oceanogr.* 16(8):1378-1398.

Tabata, S., and J. L. Peart. 1986. *Statistics of Oceanographic Data Based on Hydrographic/STD Casts Made at Stations 1 through 6 along Line P during January 1959 through June 1981.* Can. Data Rep. Hydrog. Ocean Sci. No. 38:447 p.

Tabata, S., and J. L. Peart. 1986. *Statistics of Oceanographic Data Based on Hydrographic/STC Casts Made at Stations 7 through 12 along Line P during January 1959 through June 1981.* Can. Data Rep. Hydrog. Ocean Sci. No. 43:402 p.

Tait, B. J., S. T. Grant, D. St. Jacques, and F. E. Stephenson. 1986. Canadian Arctic tide measurement techniques and results. *Int. Hydrographic Review* LXIII(2):111-31.

Thomas, D. J., R. W. Macdonald, and A. B. Cornford. 1986. Geochemical mass-balance calculations for the coastal Beaufort Sea, N.W.T., Canada. *Rapp. P.-v Reun. Cons. int. Explor. Mer.* 186:165-184.

Thomas, D. J., R. W. Macdonald, and A. G. Francis. 1986. *West Coast Data Inventory and Appraisal. Dixon Entrance, Hecate Strait, Queen Charlotte Sound and Adjoining B.C. Coastal Waters: Chemical Oceanography - 1937 through 1984.* Can. Data Rep. Hydrog. Ocean Sci. No. 37 (Vol. 3, Part 1:278 p; Part 2:248 p.)

Thompson, J. A. J., M. D. Nassichuk, D. W. Paton, B. J. Reid, and M. A. Farrell. 1986. *Examination of Tissue Metal Burdens and Metal Binding Proteins in the Golden King Crab* (Lithodes aequispina

Benedict) *from Alice Arm and Hastings Arm, B.C.* Can. Tech. Rept. of Fisheries and Aquatic Sci. No. 1440:44 p.

Thomson, R. E. 1986. The Queen Charlotte Islands: physical oceanography. In *Proc. of Queen Charlotte Islands Symposium*, ed. G. Scudder. U.B.C. Press, Vancouver.

Thomson, R. E., and W. J. Emery. 1986. The Haida current. *J. Geophys. Res.* 91(C1):845-861.

Thomson, R. E., B. M. Hickey, and P. H. LeBlond. 1986. *Water Property Observations from the Vancouver Island Coastal Current Experiment: June, July and October 1984.* Can. Data Rep. Hydrog. Ocean Sci. No. 46.

Whitney, F. A. 1986. *Metal Fluxes from False Creek Sediments under Various Chemical and Biological Conditions.* MEEE Group Data Report.

Wiegand, R., and E. Carmack. 1986. Climatology of internal waves in a deep, temperate latitude lake. *J. Geophys. Res.* 91:3951-3958

Wong, C. S., F. A. Whitney, W. K. Johnson, X. Lu, J. Wu, S. Wu, and J. Li. 1986. The effect of mine tailings on levels of heavy metals in seawater. *Acta Oceanologica Sinica* 5(3):401-415.

Wood, S. M. (ed.). 1986. *Report on Ocean Dumping R & D Department of Fisheries and Oceans 1986-1987.* Can. Contr. Rep. Hydrog. Ocean Sci. No. 26.

Woodward, M. J. 1986. An evaluation of the Aanderaa RCM4 current meter in the wave zone. In *Oceans 85 Conference Record* 2(E8):755-762

Wu, J., F. A. Whitney, and C. S. Wong. 1986. Measurement of primary production in an enclosed water column. *Acta Oceanologica Sinica* 5(4):584-592.

Biological Sciences Branch

(1) Primary Publications

Bakkala, R., T. Maeda, and G. McFarlane. 1986. Distribution and stock structure of pollock (*Theragra chalcogramma*) in the North Pacific Ocean. *INPFC Bull.* No. 45:3-20.

Balcomb, K. C., and M. A. Bigg. 1986. Population biology of the three resident killer whale pods in Puget Sound and off southern Vancouver Island. In *Behavioural biology of killer whales*, ed. B. C. Kirkevold and J. S. Lockard, 89-95. Zoo. Biol. Monogr., Vol. 1, Alan R. Liss Inc., N.Y.

Beacham, T. D. 1986. Type, quantity, and size of food of Pacific salmon (*Oncorhynchus*) in the Strait of Juan de Fuca, British Columbia. *Fish. Bull.* 84:77-89.

Beacham, T. D., and C. B. Murray. 1986. Comparative developmental biology of pink salmon (*Oncorhynchus gorbuscha*) in southern British Columbia. *J. Fish. Biol.* 28:233-246.

Beacham, T. D., and C. B. Murray. 1986. Comparative developmental biology of chum salmon (*Oncorhynchus keta*) from the Fraser River, British Columbia. *Can. J. Fish. Aquat. Sci.* 43:252-262.

Beacham, T. D., and C. B. Murray. 1986. Sexual dimorphism in length of upper jaw and adipose fin of immature and maturing Pacific salmon (*Oncorhynchus*). *Aquaculture* 58:269-276.

Beacham, T. D., and C. B. Murray. 1986. The effect of spawning time and incubation temperature on meristic variation in chum salmon (*Oncorhynchus keta*). *Can. J. Zool.* 64:45-48.

Beamish, Richard J., and Ruth E. Vithler. 1986. A polymorphic population of lampreys that may produce parasitic and nonparasitic varieties. In *Indo-Pacific Fish Biology: Proc. Second International Conference on Indo-Pacific Fishes*, ed. T. Uyeno, R. Arai, T. Taniuchi and K. Matsuura, 1986:31-49, Ichthyological Society of Japan, Tokyo.

Bell, G. R., and G. S. Traxler. 1986. Resistance of the Pacific lamprey, *Lampetra tridentata* (Gairdner), to challenge by *Renibacterium salmoninarum*, the causative agent of kidney disease in salmonids. *J. Fish. Dis.* 9(3):277-279.

Bell, G. R., D. Slind, and J. W. Bagshaw. 1986. *Pictorial atlas of histology of the sablefish* (Anoplopoma fimbria). Can. Spec. Publ. Fish. Aquat. Sci. 94:93 p.

Benfey, T. J., and D. A. Methven. 1986. Pilot-scale rearing of larval and juvenile lumpfish (*Cyclopterus lumpus L.*), with some notes on early development. *Aquaculture* 56:301-306.

Bernard, F. R. 1986. Crassodoma gen. nov. for *"Hinnites" giganteus* (Gray, 1825) from the Northeastern Pacific Ocean (Bivalvia:Pectinidae). *Venus* 45(1):69-73.

Beverley-Burton, M., T. E. McDonald, and D. Murith. 1986. Monogenea from some marine fishes taken off the Pacific Coast of Canada. *J. Parasitol.* 72(3):479-480.

Bigg, M. A., G. M. Ellis, and K. C. Balcomb, III. 1986. The photographic identification of individual cetaceans. *Whalewatcher* (Summer):10-12.

Bigg, M. A., and V. B. Scheffer. 1986. Killer whale. In *Marine mammals of eastern North Pacific and Arctic waters*, ed. D. Haley, 140-147. Pacific Seattle Press. Seattle.

Bigg, M. A. 1986. Arrival times of northern fur seals (*Callorhinus ursinus*) at the Pribilof Islands, Alaska. *Fish. Bull.* 84:383-394.

Bigg, M. A. 1986. Foreword. In *Behavioural biology of killer whales*, ed. B. C. Kirkevold and J. S. Lockard, p. xv-xvi. *Zoo. Biol. Monogr.*, Vol. 1, Alan R. Liss Inc., N.Y.

Bigg, M. A. 1986. *Situation de l'otarie de Steller* (Eumetopias jubatus) *et de l'otarie de Californie* (Zalophus californianus) *en Colombie-Britannique*. Publ. spec. can. sci. halieut. aquat. 77:27 p.

Bourne, N. 1986. Bivalve Fisheries: Their exploitation and management with particular reference to the

northeast Pacific region. In *North Pacific workshop on stock assessment and management of invertebrates*, ed. G. S. Jamieson and N. Bourne, 2-13. Can. Spec. Publ. Fish. Aquat. Sci. 92.

Boutillier, J. A. 1986. Shrimp. In *Invertebrate and marine plant fishery resources of British Columbia*, ed. G. S. Jamieson and K. Francis, 58-64. Can. Spec. Publ. Fish. Aquat. Sci. 91.

Breen, P. A. 1986. Management of the British Columbia fishery for northern abalone (*Haliotis kamtschatkana*). In *North Pacific workshop on stock assessment and management of invertebrates*, ed. G. S. Jamieson and N. Bourne, 300-312. Can. Spec. Pub. Fish. Aquat. Sci. 92.

Chilton, D. E., and H. T. Bilton. 1986. New method for ageing chinook salmon (*Oncorhynchus tshawytscha*) using dorsal fin rays, and evidence of its validity. *Can. J. Fish. Aquat. Sci.* 43:1588-1594.

Clarke, W. C., and J. E. Shelbourn. 1986. Delayed photoperiod produces more uniform growth and greater seawater adaptability in underyearling coho salmon (*Oncorhynchus kisutch*). *Aquaculture* 56:287-299.

Donaldson, E. M. 1986. The integrated development and application of controlled reproduction techniques in Pacific salmonid aquaculture. *Fish Physiol. Biochem.* 2:9-24.

Dye, H. M., J. P. Sumpter, U. H. M. Fagerlund, and E. M. Donaldson. 1986. Changes in reproductive parameters during the spawning migration of pink salmon (*Oncorhynchus gorbuscha*). *J. Fish Biol.* 29:167-176.

Evelyn, T. P. T., J. E. Ketcheson, and L. Prosperi-Porta. 1986. Use of erythromycin as a means of preventing vertical transmission of *Renibacterium salmoninarum*. *Dis. Aquat. Org.* 2(1):7-11.

Evelyn, T. P. T., L. Prosperi-Porta, and J. E. Ketcheson. 1986. Experimental intra-ovum infection of salmonid eggs with *Renibacterium salmoninarum* and vertical transmission of the pathogen with such eggs despite their treatment with erythromycin. *Dis. Aquat. Org.* 1(3):197-202.

Evelyn, T. P. T., L. Prosperi-Porta, and J. E. Ketcheson. 1986. Persistence of the kidney-disease bacterium, *Renibacterium salmoninarum*, in coho salmon, *Oncorhynchus kisutch* (Walbaum), eggs treated during and after water-hardening with povidone-iodine. *J. Fish Dis.* 9(5):461-464.

Groot, C., T. P. Quinn, and T. J. Hara. 1986. Responses of migrating adult sockeye salmon (*Oncorhynchus nerka*) to population-specific odours. *Can. J. Zool.* 64:926-932.

Hankin, D., and M. C. Healey. 1986. Dependence of exploitation rates for maximum yield and stock collapse on age and sex structure of chinook salmon (*Oncorhynchus tshawytscha*) stocks. *Can. J. Fish. Aquat. Sci.* 43:1746-1759.

Hardy, F. J., K. S. Shortreed, and J. G. Stockner. 1986. Bacterioplankton, phytoplankton, and zooplankton communities in a British Columbia coastal lake before and after nutrient reduction. *Can. J. Fish. Aquat. Sci.* 43:1504-1514.

Hargreaves, N. B., and R. J. LeBrasseur. 1986. Size selectivity of coho (*Oncorhynchus kisutch*) preying on juvenile chum salmon (*O. keta*). *Can J. Fish. Aquat. Sci.* 43:581-586.

Hay, D. E. 1986. Effects of delayed spawning on viability of eggs and larvae of Pacific herring. *Trans. Amer. Fish. Soc.* 115:155-161.

Hay, D. E., Cooke, K. D., and C. V. Gissing. 1986. Experimental studies of Pacific herring gillnets. *Fish. Res.* 4:191-211.

Healey, M. C. 1986. Optimum size and age at maturity in Pacific salmon and effects of size selective fisheries. In *Salmonid age at maturity*, ed. D. J. Meerburg, 39-52. Can. Spec. Pub. Fish. Aquat. Sci. 89.

Holtby, L. B., and M. C. Healey. 1986. Selection for adult size in female coho salmon (*Oncorhynchus kisutch*). *Can. J. Fish. Aquat. Sci.* 43:1946-1959.

Hoskins, G. E., and D. Kieser. 1986. The occurrence of proliferative kidney disease in British Columbia. In *Proliferative Kidney Disease (PKD) in North America. (Proc. of a Workshop on Proliferative Kidney Disease (PKD) among Salmonid Fish in North America.)*, 23 p. University of California, Davis, California, U.S.A.

Hunter, G. A., I. I. Solar, I. Baker, and E. M. Donaldson. 1986. Feminization of coho salmon (*Oncorhynchus kisutch*) and chinook salmon (*Oncorhynchus tshawytscha*) by immersion of alevins in a solution of estradiol-17. *Aquaculture* 53:295-302.

Irvine, J. R. 1986. Effects of varying discharge on the downstream movement of salmon fry, *Oncorhynchus tshawytscha*, Walbaum. *J. Fish. Biol.* 28:17-28.

Jamieson, G. S., and J. F. Caddy. 1986. Research advice and its application to management of shellfish resources: a workshop overview. In *North Pacific workshop on stock assessment and management of invertebrates*, ed. G. S. Jamieson and N. Bourne, 416-424. Can. Spec. Pub. Fish. Aquat. Sci. 92.

Jamieson, G. S., and K. Francis (ed.). 1986. *Invertebrate and marine plant fishery resources of British Columbia.* Can. Spec. Publ. Fish. Aquat. Sci. 91:89 p.

Jamieson, G. S., and N. Bourne (ed.). 1986. *North Pacific workshop on stock assessment and management of invertebrates.* Can. Spec. Pub. Fish. Aquat. Sci. 92:430 p.

Jamieson, G. S. 1986. A perspective on invertebrate fisheries management - the British Columbia experience. In *North Pacific workshop on stock assessment and management of invertebrates*, ed. G. S. Jamieson and N. Bourne, 57-74. Can. Spec. Publ. Fish. Aquat. Sci. 92.

Jamieson, G. S. 1986. Implications of fluctuations in recruitment in selected crab populations. *Can. J. Fish. Aquat. Sci. 43:2085-2098.*

Jensen, J. O. T., J. Schnute, and D. F. Alderdice. 1986. Assessing juvenile salmonid response to gas supersaturation using a general multivariate dose-response model. *Can. J. Fish. Aquat. Sci.* 43:1694-1709.

Kabata, Z. 1986. Redescriptions of and comments on four little-known Lernaeopodidae (Crustacea: Copepoda). *Can. J. Zool.* 64:1852-1859.

Kabata, Z. 1986. Type specimens of *Ergasilus funduli* Kroyer, 1863 (Crustacea: Copepoda) re-

examined. *Steenstrupia* 12(9):153-156.

Kabata, Z., and D. J. Whitaker. 1986. Distribution of two species of Kudoa (Myxozoa: Multivalvulida) in the offshore population of the Pacific hake, *Merluccius productus* (Ayres, 1855). *Can. J. Zool.* 64:2103-2110.

Kabata, Z., D. J. Whitaker, and J. W. Bagshaw. 1986. *Kudoa thyrsitis* (Gilchrist) (Myxosporea: Multivalvulida) in coho salmon, *Oncorhynchus kisutch* (Walbaum). *Can. J. Zool.* 64:1038-1040.

Kathman, R. D., W. C. Austin, J. C. Saltman, and J. D. Fulton. 1986. *An identification manual to the Mysidacea and Euphausiacea of the Northeast Pacific.* Can. Spec. Publ. Fish. Aquat. Sci. 93:411 p.

Ketchen, K. S. 1986. *The spiny dogfish (Squalus acanthias)* in the Northeast Pacific and a history of its utilization. Can. Spec. Publ. Fish. Aquat. Sci. 88:78 p.

Knoechel, R., and L. B. Holtby. 1986. Cladoceran filtering rate: body-length relationships for bacterial and large algal particles. *Limnol. Oceanogr.* 31(1):195-200.

Knoechel, R., and L. B. Holtby. 1986. Construction and validation of a body-length based model for the prediction of cladoceran community filtering rates. *Limnol. Oceanogr.* 31(1):1-16.

Levings, C. D. 1986. Consumptive and non-consumptive uses of vegetation in Pacific Northwest aquatic ecosystems. In *Wetland functions, rehabilitating and creation in the Pacific Northwest: state of our understanding*, ed. R. Strickland, 95-113. Wash. State Dept. of Ecology, Pub. No. 86-14.

Levings, C. D., C. D. McAllister, and B. D. Chang. 1986. Differential use of the Campbell River estuary, British Columbia, by wild and hatchery-reared juvenile chinook salmon (*Oncorhynchus tshawytscha*). *Can. J. Fish. Aquat. Sci.* 43:1386-1397.

Lundqvist, H., W. C. Clarke, L.-O. Eriksson, P. Funegard, and B. Engstrom. 1986. Seawater adaptability in three different river stocks of Baltic salmon (*Salmo salar L.*) during smolting. *Aquaculture* 52:219-229.

Luternauer, J. L., R. H. Linden, S. J. Westrheim, and R. E. Thomson. 1986. Sedimentology of Amphitrite Bank, a commercially exploited groundfish habitat—southwestern continental shelf, British Columbia, Canada. *Environ. Geol. Water Sci.* 8(3):107-121.

Macdonald, J. S., and R. H. Green. 1986. Food resource utilization by five species of benthic feeding fish in Passamaquoddy Bay, New Brunswick. *Can. J. Fish. Aquat. Sci.* 43:1534-1546.

Manzer, J. I., and I. Miki. 1986. Fecundity and egg retention of some sockeye salmon (*Oncorhynchus nerka*) stocks in British Columbia. *Can. J. Fish. Aquat. Sci.* 43:1643-1655.

Margolis, L., and T. E. McDonald. 1986. Parasites of white sturgeon, *Acipenser transmontanus*, from the Fraser River, British Columbia. *J. Parasitol.* 72(5):794-796.

Mason, J. C. 1986. Fecundity of the Pacific hake, *Merluccius productus*, spawning in Canadian waters. *Fish. Bull.* 84:209-217.

Mason, J. C., and A. C. Phillips. 1986. An improved otter surface sampler. *Fish. Bull.* 84:480-484.

McBride, J. R., U. H. M. Fagerlund, H. M. Dye, and J. Bagshaw. 1986. Changes in structure of tissues and in plasma cortisol during the spawning migration of pink salmon (*Oncorhynchus gorbuscha*). *J. Fish Biol.* 29:153-165.

McFarlane, G. A., and R. J. Beamish. 1986. Production of strong year-classes of sablefish (*Anoplopoma fimbria*) off the west coast of Canada. *INPFC Bull.* 47:191-202.

McFarlane, Gordon A., and Richard J. Beamish. 1986. A tag suitable for assessing long-term movements of spiny dogfish and preliminary results from use of this tag. *N. Am. J. Fish. Manage.* 6(1):69-76.

Mulligan, T. J., and R. Kieser. 1986. Comparison of acoustic population estimates of salmon in a lake with a weir count. *Can. J. Fish. Aquat. Sci.* 43(7):1373-1385.

Mundie, J. H., and R. Bell-Irving. 1986. Predictability of the consequences of the Kemano Hydroelectric Proposal for natural salmon populations. *Can. Water Res.* J. 11:14-25.

Murray, C. B., and T. D. Beacham. 1986. Effect of density and substrate on the development of chum salmon (*Oncorhynchus keta*) eggs and alevins. *Prog. Fish-Cult.* 48:242-249.

Murray, C. B., and T. D. Beacham. 1986. Effect of varying temperature regimes on the development of pink salmon (*Oncorhynchus gorbuscha*) eggs and alevins. *Can. J. Zool.* 64:670-676.

Mysak, A. L., C. Groot, and K. Hamilton. 1986. A study of climate and fisheries: interannual variability of the northeast Pacific Ocean and its influence on homing migration rates of sockeye salmon. *Climatological Bull.* 20:26-35.

Noakes, D. 1986. Quantifying changes in British Columbia Dungeness crab (*Cancer magister*) landings using intervention analysis. *Can. J. Fish. Aquat. Sci.* 43:634-639.

Overholtz, W. J., and A. V. Tyler. 1986. An exploratory simulation model of competition and predation in a demersal fish assemblage on Georges Bank. *Trans. Amer. Fish. Soc.* 115:805-817.

Perez, M. A., and M. A. Bigg. 1986. Diet of northern fur seals *Callorhinus ursinus* off western North America. *Fish. Bull.* 84:957-970.

Phillips, A. C., and J. C. Mason. 1986. A towed, self-adjusting sled sampler for demersal fish eggs and larvae. *Fish. Res.* 4:235-242.

Porter, T. R., M. C. Healey, M. F. O'Connell, with E. T. Baum, A. T. Bielak, and Y. Cote. 1986. Implications of varying the sea age at maturity of Atlantic salmon (*Salmo salar*) on yield to the fisheries. In *Salmonid age at maturity*, ed. D. J. Meerburg, 110-117. Can. Spec. Publ. Fish. Aquat. Sci. 89.

Richards, L. J., and J. T. Schnute. 1986. An experimental and statistical approach to the question: Is CPUE an index of abundance? *Can. J. Fish. Aquat. Sci.* 43:1214-1227.

Richards, Laura J. 1986. Depth and habitat distributions of three species of rockfish (*Sebastes*) in British Columbia: Observations from the submersible PISCES IV. *Environmental Biology of Fishes* 17(1):13-21.

Richardson, N. L., D. A. Higgs, and R. M. Beames. 1986. The susceptibility of juvenile chinook salmon (*Oncorhynchus tshawytscha*) to cataract formation in relation to dietary changes in early life history. *Aquaculture* 52:237-243.

Riddell, B. E. 1986. A genetic perspective regarding selective fishing and age-at-maturity in Atlantic salmon. Can. Spec. Publ. Fish. Aquat. Sci. 89:102-109.

Riddell, B. E., and D. Sorensen. 1986. Growth rate variation between populations of coho salmon. In *Genetics in Aquaculture* II, p. 374. Elsevier Publ. N.Y.

Robert, G., and G. S. Jamieson. 1986. Commercial fishery data isopleths and their use in offshore sea scallop (*Placopecten magellanicus*) stock evaluation, p. 76-82. In G. S. Jamieson and N. Bourne (ed.) *North Pacific workshop on stock assessment and management of invertebrates.* Can. Spec. Pub. Fish. Aquat. Sci. 92.

Rogers, I. H., I. K. Birtwell, and G. M. Kruzynski. 1986. Organic extractables in municipal wastewater, Vancouver, British Columbia. *Water Poll. Res. J. Canada.* 21 (2):187-204.

Schnute, J., and J. O. T. Jensen. 1986. A general multivariate dose-response model. *Can. J. Fish. Aquat. Sci.* 43:1684-1693.

Servizi, James A., Dennis W. Martens, Robert W. Gordon, James P. Kutney, Mahatam Singh, Eugene Dimitriadis, Gary M. Hewitt, Philip J. Salisbury, and Lewis S.L. Choi. 1986. Microbiological detoxification of resin acids. *Water Poll. Res. J. of Canada.* 21(1):119-129.

Servizi, J.A., R.W. Gordon. 1986. Detoxification of TMP and CTMP effluents alternating in a pilot scale aerated lagoon. *Pulp Paper Canada* 87(11):T404-409.

Shariff, M., Z. Kabata, and C. Sommerville. 1986. Host susceptibility to *Lernaea cyprinacea* L. and its treatment in a large aquarium system. *J. Fish Dis.* 9(5):393-401.

Shaw, William, and Gordon A. McFarlane. 1986. Biology, distribution and abundance of walleye pollock (*Theragra chalcogramma*) off the west coast of Canada. *INPFC Bull.* No. 45:262-283.

Shepherd, B. G., G. F. Hartman, and W. J. Wilson. 1986. Relationships between stream and intra-gravel temperatures in coastal drainages, and some implications for fisheries workers. *Can. J. Fish. Aquat. Sci.* 43:1818-1822.

Shortreed, K. S., and J. G. Stockner. 1986. Trophic status of 19 sub-arctic lakes in the Yukon Territories. *Can. J. Fish. Aquat. Sci.* 43:797-805.

Sloan, N. A. 1986. Sea Cucumber. In *Invertebrate and marine plant fishery resources of British Columbia*, ed. G. S. Jamieson and K. Francis, 3-8. Can. Spec. Publ. Fish. Aquat. Sci. 91.

Sloan, N. A. 1986. World jellyfish and tunicate fisheries and the N.E. Pacific echinoderm fishery. In *North Pacific workshop on stock assessment and management of invertebrates*, ed. G. S. Jamieson and N. Bourne, 23-33. Can. Spec. Publ. Fish. Aquat. Sci. 92.

Smith, Barry D. 1986. The implications of population dynamics and interspecific competition for harvest management of Laminaria in Nova Scotia. *Mar. Ecol. Prog. Ser.* 33:7-18.

Stehr, C., and D. J. Whitaker. 1986. Host-parasite interaction of the myxosporeans *Kudoa paniformis* Kabata & Whitaker, 1981 and *Kudoa thyrsites* (Gilchrist, 1924) in the muscle of Pacific whiting, *Merluccius productus* (Ayres): an ultrastructural study. *J. Fish Dis.* 9(6):505-517.

Stockner, J. G., and N. J. Antia. 1986. Algal picoplankton from marine and freshwater ecosystems: a multidisciplinary perspective. *Can. J. Fish. Aquat. Sci.* 43:2472-2503.

Sumpter, J. P., and E. M. Donaldson. 1986. The development and validation of a radioimmunoassay to measure blood ACTH levels in salmonid fishes. *Gen. Comp. Endocrinol.* 62:367-376.

Sumpter, J. P., H. M. Dye, and T. J. Benfey. 1986. The effects of stress on plasma ACTH,-MSH, and cortisol levels in salmonid fishes. *Gen. Comp. Endocrinol.* 62:377-385.

Swales, S., R. B. Laurier, and C. D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. *Can. J. Zool.* 64:1506-1514.

Thomas, Wm. K., R. E. Withler, and A. T. Beckenbach. 1986. Mitochondrial DNA sequence evolution in Pacific salmonids. *Can. J. Zool.* 64:1058-1064.

Traxler, G. S. 1986. An epizootic of infectious haematopoietic necrosis in 2-year-old kokanee, *Oncorhynchus nerka* (Walbaum) at Lake Cowichan, British Columbia. *J. Fish Dis.* 9(6):545-549.

Tyler, A. V., and S. J. Westrheim. 1986. Effects of transport, temperature, and stock size on recruitment of Pacific cod (*Gadus macrocephalus*). *INPFC Bull.* 47:175-189.

Van Der Kraak, G., and E. M. Donaldson. 1986. Steroidogenic capacity of coho salmon ovarian follicles throughout the periovulatory period. *Fish Biochem. Physiol.* 1:179-186.

Van Der Kraak, G., E. M. Donaldson, and J. P. Chang. 1986. Dopamine involvement in the regulation of gonadotropin secretion in coho salmon. *Can. J. Zool.* 64:1245-1248.

Waldichuk, M. 1986. Biological availability of metals as a factor in monitoring marine sediments for pollution. In *Integrated Global Ocean Monitoring: Proc. of the 1st International Symposium*, Vol. 2, ed. Yu. A. Israel, A. V. Tsyban, A. S. Sarkisyan, S. P. Barinova, O. E. Geroimenkova, and V. O. Mamayev, 30-61. Leningrad Gidrometeoizdat, U.S.S.R.

Waldichuk, M. 1986. Management of the estuarine ecosystem against cumulative effects of pollution and development. In *Proceedings of the Workshop on Cumulative Environmental Effects: A Binational Perspective*, ed. G. E. Beanlands, W. J. Erckmann, G. H. Orians, J. O'Riordan, D. Policansky, M. H. Sadar, and B. Sadler, 93-105. The Canadian Environmental Assessment Research Council (CEARC), Ottawa, and U.S. National Research Council (NRC), Washington, D.C.

Walters, C., and B. Riddell. 1986. Multiple objectives in salmon management: The chinook sport fishery in the Strait of Georgia, B.C. *Northwest Envir. J.* 2(1):15.

Walters, Carl J., M. Stocker, A. V. Tyler, and S. J. Westrheim. 1986. Interaction between Pacific cod

(*Gadus macrocephalus*) and herring (*Clupea harengus pallasi*) in Hecate Strait, British Columbia. *Can. J. Fish. Aquat. Sci.* 43:830-837.

Ware, D. M., and G. A. McFarlane. 1986. Relative impact of Pacific hake, sablefish and Pacific cod on west coast of Vancouver Island herring stocks. *INPFC Bull.* 47:67-77.

Welch, D. W. 1986. Identifying the stock-recruitment relationship for age-structured populations using time-invariant matched linear filters. *Can. J. Fish. Aquat. Sci.* 43:108-123.

Westrheim, S. J., and R. P. Foucher. 1986. Fluctuations in year-class abundance of Pacific cod (*Gadus macrocephalus*) off western Canada. *INPFC Bull.* 45:287-294.

Whyte, J. N. C., J. R. Englar, B. L. Carswell, and K. E. Medic. 1986. Influence of starvation and subsequent feeding, on body composition and energy reserves in the prawn *Pandalus platyceros* Brandt. *Can. J. Fish. Aquat. Sci.* 43:1142-1148.

Williams, I. V., and J. R. Brett. 1986. The critical swimming speed of Fraser and Thompson River pink salmon. *Can. J. Fish. Aquat. Sci.* 43:348-356.

Williams, I. V., J. R. Brett, G. R. Bell, G. S. Traxler, J. Bagshaw, J. R. McBride, U. H. M. Fagerlund, H. M. Dye, J. P. Sumpter, E. M. Donaldson, E. Bilinski, H. Tsuyuki, M. D. Peters, E. M. Choromanski, J. H. Y. Cheng, and W. L. Coleridge. 1986. The 1983 early run Fraser and Thompson River pink salmon; morphology, energetics and fish health. *Int. Pac. Salmon Fish. Comm. Bull.* 23:55 p.

Withler, R. E. 1986. Genetic variation in carotenoid pigment deposition in the red-fleshed and white-fleshed chinook salmon (*Oncorhynchus tshawytscha*) of Quesnel River, British Columbia. *Can. J. Gen. Cyt.* 28:587-594.

Withler, R. E., J. D. McPhail, and R. H. Devlin. 1986. Electrophoretic polymorphism and sexual dimorphism in the freshwater and anadromous threespine sticklebacks (*Gasterosteus aculeatus*) of the Little Campbell River, British Columbia. *Biochem. Genet.* 24:701-713.

Wood, C. C. 1986. Dispersion of common merganser (*Mergus merganser*) breeding pairs in relation to the availability of juvenile Pacific salmon in Vancouver Island streams. *Can. J. Zool.* 64:756-765.

Youson, John H., and Richard J. Beamish. 1986. Morphological comparison of organs in several species of lampreys on the west coast of Canada. In *Indo-Pacific Fish Biology: Proc. of the Second International Conference on Indo-Pacific Fishes*, ed. T. Uyeno, R. Arai, T. Taniuchi and K. Matsuura, 1986, p. 926. Ichthyological Society of Japan, Tokyo.

(2) Other Publications

Barner, L. W., C. B. Murray, and T. D. Beacham. 1986. *Size, age, meristics and morphometrics of chum salmon returning to British Columbia during 1983-1985.* Can. Tech. Rep. Fish. Aqua Sci. 1484:42p.

Birtwell, I. K., and G. M. Kruzynski. 1986. A laboratory apparatus for studying organisms in stratified waters. In *Proc. eleventh annual aquatic toxicity workshop: November 13-15, 1984. Vancouver, B. C.*, ed. G. H. Geen and K. L. Woodward, 173-177. Can. Tech. Rep. Fish. Aquat. Sci. 1480.

Birtwell, I. K., and J. Andrew. 1986. Effects of biota. In *Toxic chemicals research needs in the lower Fraser River: workshop proceedings*, 71-88. Environment Canada, Regional Toxic Chemicals Committee, Vancouver, B.C.

Bower, S. M., R. Harbo, B. Adkins, and N. Bourne. 1986. *Investigation of Manila clam* (Tapes philippinarum) *mortalities during the spring of 1985 in the Strait of Georgia, with a detailed study of the problem on Savary Island, British Columbia.* Can. Tech. Rep. Fish. Aquat. Sci. 1444:25 p.

Brown, T. J., B. A. Kask, M. S. Kotyk, C. D. McAllister, C. D. Levings, and J. S. Macdonald. 1986. *Salmonid catch-data from Campbell River and Discovery Passage, 1986.* Can. Data Rep. Fish. Aquat. Sci. 617:61 p.

Brown, T. J., B. A. Kask, C. D. McAllister, M. S. Kotyk, C. D. Levings, and J. S. Macdonald. 1986. *Campbell River zooplankton samples.* Can. Data Rep. Fish. Aquat. Sci. 618:29 p.

Brown, T. J., B. A. Kask, C. D. McAllister, M. Kotyk, C. D. Levings, and J. S. Macdonald. 1986. 1985 *Campbell River zooplankton samples.* Can. Data Rep. Fish. Aquat. Sci. 572:45 p.

Burt, D. W., and J. H. Mundie. 1986. *Case histories of regulated stream flow and its effects on salmonid populations.* Can. Tech. Rep. Fish. Aquat. Sci. 1477:98 p.

Byres, R. D., and J. A. Servizi. 1986. *Dissolved atmospheric gases and reaeration coefficients for the Nechako River.* Can. Tech. Rep. Fish. Aquat. Sci. 1459:83 p.

Carmichael, J. R., and N. Bourne. 1986. *Proposed techniques for the assessment of recreational invertebrate harvest in British Columbia.* Can. MS Rep. Fish. Aquat. Sci. 1869:30 p.

Carter, E. W., L. A. Lapi, and E. A. R. Ball. 1986. *Catch, size, and age of chinook and coho salmon taken in the Strait of Georgia troll fishery in 1983.* Can. Data Rep. Fish. Aquat. Sci. 585:96 p.

Carter, E. W., L. A. Lapi, and E. A. R. Ball. 1986. *Catch, size and age of chinook and coho salmon taken in the Strait of Georgia troll fishery in 1984 and comparisons with 1983 data.* Can. Tech. Rep. Fish. Aquat. Sci. 1456:73 p.

Cass, A. J. 1986. 2. Lingcod. In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986*, ed. A. V. Tyler, R. P. Foucher and J. Fargo, 2-12. Can. MS. Rep. Fish. Aquat. Sci. 1897.

Cass, A. J., G. A. McFarlane, M. S. Smith, I. Barber, and K. Rutherford. 1986. *Lingcod tagging in the Strait of Georgia, 1983-84.* Can. MS. Rep. Fish. Aquat. Sci. 1875:49 p.

Cass, A. J., J. R. Selsby, and L. J. Richards. 1986. *Lingcod maturity cruise off southwest Vancouver Island and in Queen Charlotte Sound, R/V G. B. Reed, August 20-September 5, 1985.* Can. Data Rep. Fish. Aquat. Sci. 594. 78 p.

Cass, A. J., L. J. Richards, and J. R. Selsby. 1986. *A summary of rockfish samples collected from the*

commercial handline fishery in Statistical Area 13 between July 1984 and March 1985. Can. MS Rep. Fish. Aquat. Sci. 1881:49 p.

Fargo, J. 1986. 4. Flatfish.In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986*, ed. A. V. Tyler, R. P. Foucher and J. Fargo, 16-29. Can. MS Rep. Fish. Aquat. Sci. 1897.

Fargo, J., and D. Davenport. 1986. *F/V Double Decker species assemblage survey of Hecate Strait, Jan. 30-Feb. 19, 1986.* Can. Data Rep. Fish. Aquat. Sci. 603:106 p.

Fargo, J., and S. J. Westrheim. 1986. *Results of the annual trawl surveys of juvenile flatfish in Hecate Strait, 1980-85.* Can. MS Rep. Fish. Aquat. Sci. 1884:71 p.

Fleming, J. O., J. S. Nathan, C. MacPherson, and C. D. Levings. 1986. *Survey of juvenile salmonids in gravity-fed irrigation ditches, Nicola and Coldwater River valleys, 1985.* Can. Data Rep. Fish. Aquat. Sci. 662:47 p.

Gjernes, T. W., K. D. Hyatt, and D. P. Rankin. 1986. *Development of specifications for the use of an uncalibrated echo sounder to estimate populations of small limnetic fish.* Can. Tech. Rep. Fish. Aquat. Sci. 1509:35 p.

Groot, C., K. Cooke, G. Ellis, and R. Bailey. 1986. *Data record of juvenile sockeye salmon and other fish species captured by purse seine and trawl in the Strait of Georgia, Johnstone Strait, and Queen Charlotte Strait in 1982, 1983, 1984, and 1985.* Can. Data Rep. Fish. Aquat. Sci. 561:150 p.

Haegele, C. W. (ed.). 1986. *Proc. fifth Pacific coast herring workshop, October 29-30, 1985.* Can. MS Rep. Fish. Aquat. Sci. 1871:164 p.

Haegele, C. W. 1986. Egg loss in British Columbia herring spawns. In *Proc. fifth Pacific coast herring workshop, October 29-30, 1985.* ed. C. W. Haegele, 141-142. Can. MS Rep. Fish. Aquat. Sci. 1871.

Haegele, C. W. 1986. Observed recovery rates for anchor tags in British Columbia herring. In *Proc. fifth Pacific coast herring workshop, October 29-30, 1985.* ed. C. W. Haegele, 92-93. Can. MS Rep. Fish. Aquat. Sci. 1871.

Haegele, C. W. 1986. *Returns from anchor taggings of herring in British Columbia, 1979 to 1985.* Can. Data Rep. Fish. Aquat. Sci. 582:129 p.

Haist, V. 1986. Evaluation of certain aspects of B.C. herring stock dynamics. In *Proc. fifth Pacific coast herring workshop, October 29-30, 1985.* ed. C. W. Haegele, 50-58. Can. MS Rep. Fish. Aquat. Sci. 1871.

Haist, V., J. F. Schweigert, and M. Stocker. 1986. *Stock assessments for British Columbia herring in 1985 and forecasts of the potential catch in 1986.* Can. MS Rep. Fish. Aquat. Sci. 1889:48 p.

Hamer, B. L., N. L. Venables, J. B. Lucas, and D. P. Adams. 1986. *An inventory of biological samples taken in the British Columbia groundfish fishery during 1985.* Can. Data Rep. Fish. Aquat. Sci. 606:15 p.

Hartman, G. F., and J. C. Scriven[illegible] 1986. Some strategy considerations for small stream restoration and enhancement with special emphasis on high rainfall area streams such as Carnation Creek. In *Proc. workshop on habitat improvements, May 8-10, 1984. Whistler, British Columbia*, ed. J. H. Patterson, 69-84. Can. Tech. Rep. Fish. Aquat. Sci. 1483.

Hay, D. E. 1986. A stock hypothesis based on spawn and winter distribution. In *Proc. fifth Pacific coast herring workshop, October 29-30, 1985*, ed. C. W. Haegele, 145-148. Can. MS Rep. Fish. Aquat. Sci. 1871.

Hay, D. E., and P. B. McCarter. 1986. Feeding and summer distribution of herring and other pelagic fishes. In *Hecate Strait Project: results of the first two years of multispecies research*, ed. A. V. Tyler, 20-21. Can. Tech. Rep. Fish. Aquat. Sci. 1470:50 p.

Hay, D. E. 1986. Larval herring distribution in Hecate Strait. In *Hecate Strait Project: results of the first two years of multispecies research*, ed. A. V. Tyler, p. 31. Can. Tech. Rep. Fish. Aquat. Sci. 1470:50 p.

Hay, D. E., R. Kieser, and P. B. McCarter. 1986. Distribution of herring in Winter. In *Hecate Strait Project: results of the first two years of multispecies research*, ed. A.V. Tyler, 11-15. Can. Tech. Rep. Fish. Aquat. Sci. 1470.

Healey, M. C. 1986. *Regional and seasonal attributes of catch in the British Columbia troll fishery.* Can. Tech. Rep. Fish. Aquat. Sci. 1494:65 p.

Healey, M. C., B. Riddell, F. P. Jordan, and J. F. T. Morris. 1986. The *1981-1983 west coast troll log book project: 4. Biological data for chinook* (Oncorhynchus tshawytscha) *and coho* (O. kitsutch) *salmon.* Can. Data Rep. Fish. Aquat. Sci. 573:1036 p.

Healey, M. C., B. Riddell, F. P. Jordan, and J. F. T. Morris. 1986. The *1981-1983 west coast troll log book project: 5. Data from the 1982 and 1983 seasons on the food habits of chinook* (Oncorhynchus tshawytscha) *and coho* (O. kisutch) *salmon.* Can. Data Rep. Fish. Aquat. Sci. 591:936 p.

Hyatt, K. D. 1986. Some options for habitat manipulation in B.C. coastal lakes to enhance salmonid production. In *Proc. Workshop on Habitat Improvements, Whistler, B.C., 8-10 May, 1984*, ed. J. H. Patterson, 35-37. Can. Tech. Rep. Fish. Aquat. Sci. 1483.

Jamieson, G. S., C. K. Robinson, and T. H. Butler. 1986. *King and Tanner crabs in northern British Columbia mainland inlets, May 4-June 18, 1982.* Can. MS Rep. Fish. Aquat. Sci. 1880:127 p.

Johnston, N. T., J. R. Irvine, and C. J. Perrin. 1986. *A comparative evaluation of fence count, mark-recapture and Bendix sonar estimates of salmon escapements in the Keogh River, a variable-flow coastal B.C. stream.* Can. Tech. Rep. Fish. Aquat. Sci. 1453:44 p.

Johnston, N. T., J. R. Irvine, and C. J. Perrin. 1986. *Catch, size, and tagging data for adult salmonid runs into the Keogh River, B.C., 1985.* Can. Data Rep. Fish. Aquat. Sci. 592:80 p.

Jordan, F. P., and E. W. Carter. 1986. *1985 West coast troll log program.* Can. Data Rep. Fish. Aquat. Sci. 587:48 p.

Kask, B. A., and T. J. Brown. 1986. *Epibenthic sled samples from Campbell River estuary and Discovery Passage 1984.* Can. Data Rep. Fish. Aquat. Sci. 612:141 p.

Kask, B. A., T. J. Brown, and C. D. McAllister. 1986. *Nearshore epibenthos of the Campbell River estuary and Discovery Passage, 1982, in relation to juvenile chinook diets.* Can. Tech. Rep. Fish. Aquat. Sci. 1449:53 p.

Kotyk, M. S., T. J. Brown, B. A. Kask, C. D. Levings, C. D. McAllister, and J. S. Macdonald. 1986. *Data record on coded wire tags recovered from juvenile salmonids at Campbell River estuary and Discovery Passage, 1985.* Can. Data Rep. Fish. Aquat. Sci. 581:19 p.

Kotyk, M. S., T. J. Brown, B. A. Kask, C. D. Levings, C. D. McAllister, J. S. Macdonald, and B. D. Chang. 1986. *Length and weight data for unmarked juvenile salmonids sampled in the Campbell River estuary and Discovery Passage, 1984.* Can. Data Rep. Fish. Aquat. Sci. 513:54 p.

Kreiberg, H. 1986. Progress in sac-roe impoundment research and options for management. In *Proc. fifth Pacific coast herring workshop, Oct. 29-30, 1985,* ed. C. W. Haegele, p. 37. Can. MS Rep. Fish. Aquat. Sci. No. 1871.

Kreiberg, H., J. R. Brett, A. Solmie, and R. A. Carter. 1986. *A handbook on impounding sac-roe herring.* Can. Ind. Rep. Fish. Aquat. Sci. No. 168:46 p.

Kruzynski, G. M., I. K. Birtwell, and I. H. Rogers. 1986. Studies on chinook salmon (*Oncorhynchus tshawytscha*) and municipal waste from the Iona Island Sewage Treatment Plant, Vancouver, B.C. In *Proc. eleventh annual aquatic toxicity workshop: November 13-15, 1984. Vancouver, B.C.,* ed. G. H. Geen and K. L. Woodward, 240-250. Can. Tech. Rep. Fish. Aquat. Sci. 1480.

Lauzier, R. B., and C. A. McPherson. 1986. *Length and weight data for juvenile salmonids sampled during rearing studies in the Nicola/Coldwater River system, during December 1984 and in 1985.* Can. Data Rep. Fish. Aquat. Sci. 599:165 p.

Leaman, B. M. 1986. 9. Slope rockfishes. In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986,* ed. A. V. Tyler, R. P. Foucher and J. Fargo, 57-75. Can. MS Rep. Fish. Aquat. Sci. 1897.

Leaman, B. M., and D. A. Nagtegaal. 1986. *Biomass survey of rockfish stocks in the Dixon Entrance-Southeast Alaska region, July 5-22, 1983 (R/V G. B. Reed and M/V Free Enterprise No. 1).* Can. Tech. Rep. Fish. Aquat. Sci. 1510:63 p.

Leaman, J. E. 1986. *Catch and effort statistics of the Canadian groundfish fishery on the Pacific coast in 1985.* Can. Tech. Rep. Fish. Aquat. Sci. 1508: 80 p.

McCarter, P. B., C. W. Haegele, D. C. Miller, and D. E. Hay. 1986. *Hecate Strait herring survey July 22-August 8, 1985, G. B. Reed Cruise 85-8.* Can. Data Rep. Fish. Aquat. Sci. 615:35 p.

Morley, R. B., and D. Brouwer. 1986. *A time and size at release study on chum salmon. Details of releases from Conuma Hatchery in the spring of 1985.* Can. MS Rep. Fish. Aquat. Sci. No. 1901: 20 p.

Mundie, J. H. 1986. Stream morphology and enrichment, p. 104-107. In Patterson, J. (ed.) *Proc. Habitat Improvement Workshop.* Can. Tech. Rep. Fish. Aquat. Sci. 1483.

Nagtegaal, D. A., B. M. Leaman, and R. D. Stanley. 1986. *Catches and trawl locations of R/V G. B. Reed and M/V Eastward Ho during the Pacific Ocean perch assessment cruise to Queen Charlotte Sound,*

August-September, 1984. Can. Data Rep. Fish. Aquat. Sci. 611:109 p.

Noakes, D., and G. S. Jamieson. 1986. *Preliminary analysis of British Columbia commercial landing statistics for 1979 to 1984 inclusive: a multispecies approach.* Can. MS Rep. Fish. Aquat. Sci. 1882:191 p.

Quinn, T. P., K. D. Cooke, and G. Ellis. 1986. *The responses of adult sockeye salmon* (Oncorhynchus nerka) *to a commercial purse seine.* Can. Tech. Rep. Fish. Aquat. Sci. 1511:13 p.

Rankin, D. P., and J. E. Radziul. 1986. *Zooplankton abundance and size in British Columbia lakes sampled by the lake enrichment program in 1980.* Can. Data Rep. Fish. Aquat. Sci. 589:174 p.

Rankin, D. P., and J. E. Radziul. 1986. *Zooplankton abundance and size in British Columbia lakes sampled by the lake enrichment program in 1979.* Can. Data Rep. Fish. Aquat. Sci. 588:9 p.

Richards, L. J. 1986. PSARC Working Paper G86-1. *1986 Assessment for commercially exploited rockfish stocks in the Strait of Georgia.* Can. MS Rep. Fish. Aquat. Sci. 1885:55 p.

Richards, L. J., H. I. McElderry, J. Carolsfeld, and C. P. Lauridsen. 1986. *SCUBA survey of rockfish assemblages in the Strait of Georgia, B.C. Statistical Areas 15 and 16), September to November 1985.* Can. Data Rep. Fish. Aquat. Sci. 586:112 p.

Rogers, I. H., I. K. Birtwell, and G. M. Kruzynski. 1986. *Organic extractables in primary treated municipal wastewater and uptake in exposed juvenile chinook salmon. A preliminary study at Iona Island sewage treatment plant, Vancouver, B.C.* Can. Tech. Rep. Fish. Aquat. Sci. 1433:35 p.

Rosenfeld, L., and V. Haist. 1986. *Summary of British Columbia herring sampling data for the 1985-86 season.* Can. Data Rep. Fish. Aquat. Sci. 619:125 p.

Rutherford, D. T., K. D. Hyatt, J. E. Radziul, and G. J. Steer. 1986. *Physical parameters of sockeye salmon* (Oncorhynchus nerka) *rearing lakes under study by the Enhancement Assessment Unit.* Can. MS. Rep. Fish. Aquat. Sci. 1878:119 p.

Saunders, M. 1986. 5. Sablefish. In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986,* ed. A. V. Tyler, R. P. Foucher and J. Fargo, 30-34. Can. MS Rep. Fish. Aquat. Sci. 1897.

Saunders, M. 1986. 7. Dogfish. In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986,* ed. A. V. Tyler, R. P. Foucher and J. Fargo, 41-50. Can. MS Rep. Fish. Aquat. Sci. 1897.

Saunders, M., and W. Shaw. 1986. 8. Walleye pollock. In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986,* ed. A. V. Tyler, R. P. Foucher and J. Fargo, 51-56. Can. MS Rep. Fish. Aquat. Sci. 1897.

Saunders, M. W., R. P. Foucher, A. V. Tyler, and D. F. Moore. 1986. *Groundfish food-resource division sub-project of the Hecate Strait Project R/V G. B. Reed cruises in Hecate Strait, B.C., during June 7-17, and September 23-October 4, 1985.* Can. Data Rep. Fish. Aquat. Sci. 602:209 p.

Schweigert, J. F. 1986. A multivariate approach to describe Pacific herring stocks from size at age and

age structure information. In *Proc. fifth Pacific coast herring workshop, October 29-30, 1985*, ed. C. W. Haegele, 149-150. Can. MS Rep. Fish. Aquat. Sci. 1871.

Shaw, W., and M. Saunders. 1986. 6. Pacific hake. In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986.* ed. A. V. Tyler, R. P. Foucher and J. Fargo, 35-40. Can. MS Rep. Fish. Aquat. Sci. 1897.

Shaw, W., G. A. McFarlane, and S. E. MacLellan. 1986. *Biological survey of Pacific hake, walleye pollock and spiny dogfish in the Strait of Georgia. R/V G. B. Reed, March 19-30, 1984.* Can. Data Rep. Fish. Aquat. Sci. 590:95 p.

Shirvell, C. S. 1986. *Pitfalls of physical habitat simulation in the instream flow incremental methodology.* Can. Tech. Rep. Fish. Aquat. Sci. 1460:68 p.

Solar, I. I., I. J. Baker, E. M. Donaldson, G. A. Hunter, and E. T. Stone. 1986. *Coded wire tag recoveries from the first release of all-female and sterile groups of coho salmon* (O. kitsutch) *into the marine environment.* Can. Data Rep. Fish. Aquat. Sci. No. 609:29 p.

Stanley, R. 1986. 10. Shelf rockfish (silvergray, yellowtail, canary rockfish). In *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986*, ed. A. V. Tyler, R. P. Foucher and J. Fargo, 76-104. Can. MS Rep. Fish. Aquat. Sci. 1897.

Steer, G. J., N. B. F. Cousens, H. Stiff, and K. D. Hyatt. 1986. *An analysis of gear selectivity and sources of bias in estimates of age and stock composition of the 1980-1984 Barkley Sound sockeye salmon* (Oncorhynchus nerka) *catch.* Can. Tech. Rep. Fish. Aquat. Sci. 1445:81 p.

Stocker, M. 1986. Environmental-dependent Ricker stock-recruitment models for Pacific herring (*Clupea harengus pallasi*). In *Proc. fifth Pacific coast herring workshop, October 29-30, 1985*, ed. C. W. Haegele, 119-125. Can. MS Rep. Fish. Aquat. Sci. 1871.

Stocker, M. 1986. Forecasting year-class strengths of Pacific herring using environment-dependent Ricker stock-recruitment models. In *Hecate Strait project: research results of the first two years*, ed. A. V. Tyler, 32-35. Can. Tech. Rep. Fish. Aquat. Sci. 1470:50 p.

Tanasichuk, R. W., and D. M. Ware. 1986. The influence of inter-annual variations in winter sea temperatures on the fecundity and egg size of Pacific herring. In *Proc. fifth Pacific Coast herring Workshop, October 29-30, 1985*, ed. C. W. Haegele, p. 105. Can. MS Rep. Fish. Aquat. Sci. 1871.

Tyler, A. V. (ed.). 1986. *Hecate Strait Project: Results of the first two years of multispecies fisheries research.* Can. Tech. Rep. Fish. Aquat. Sci. 1470:50 p.

Tyler, A. V., L. J. Richards, and C. J. Walters. 1986. *Hecate Strait Project report on the Hecate Strait ecosystem modelling workshop.* Can. MS Rep. Fish. Aquat. Sci. 1879:23 p.

Tyler, A. V., R. P. Foucher, and J. Fargo (ed.). 1986. *Groundfish stock assessments for the west coast of Canada in 1985 and recommended yield options for 1986.* Can. MS Rep. Fish. Aquat. Sci. 1897: 108 p.

Tyler, A. V., S. J. Westrheim, and R. P. Foucher. 1986. 3. Pacific cod, p. 13-15. In A. V. Tyler, R. P. Foucher and J. Fargo. (ed.) *Groundfish stock assessment for the west coast of Canada in 1985 and*

recommended yield options for 1986. Can. MS Rep. Fish. Aquat. Sci. 1897.

Vespestad, V., and M. Stocker. 1986. Workshop summary. In *Proc. Fifth Pacific Coast Herring Workshop*, October 29-30, 1985, ed. C. W. Haegele, 163-164. Can. MS Rep. Fish. Aquat. Sci. 1871.

Welch, D., and R. P. Foucher. 1986. Analysis of natural population regulation in Hecate Strait Pacific cod. In *Hecate Strait project: results of the first two years of multispecies fisheries research*, ed. A. V. Tyler, 49-50. Can. Tech. Rep. Fish. Aquat. Sci. 1470.

Westrheim, S. J., and M. G. Pedersen. 1986. *An anomalous Pacific cod fishery in Juan de Fuca Strait.* Can. MS Rep. Fish. Aquat. Sci. 1891:55 p.

Whitaker, D. J. 1986. *Intensity of infection by two species of the myxosporean parasite Kudoa and its distribution in six areas of the flesh of Pacific hake* (Merluccius productus). Can. Data Rep. Fish. Aquat. Sci. 598:23 p.

Withler, R. E., W. C. Clarke, B. E. Riddell, and H. Kreiberg. 1986. *Freshwater survival and growth of chinook salmon* (Oncorhynchus tshawytscha) *under hatchery conditions.* Can. Data Rep. Fish. Aquat. Sci. 583:37 p.

Appendix II

Permanent Staff 1986/87

Regional Director of Science

Davis, J.C.; B.Sc., M.Sc., Ph.D. (Brit. Col.)

Cornford, A.B.; B.Sc. (McMaster), Ph.D. (Brit. Col.)
McDonald, L.J.

Hydrography

Director of Hydrography:

O'Connor, A.D.; C.L.S.

Ages, A.B.; B.A.Sc., M.A.Sc. (Brit. Col.), P.Eng.
Bell, R.D.
Canning, B.
Chan, L.M.
Chapeskie, R.E.
Coldham, F.A.
Crawford, W.R.; B.Sc., M.A.Sc. (Waterloo), Ph.D. (Brit. Col.)
Crowley, J.V.; C.L.S.
Crowther, W.S.; CC (Ont. Inst. Chartered Cartographers)

Curran, T.A.; B.A.Sc. (EE), M.Sc. (Brit. Col.), P.Eng.
Czotter, K.L.; Dip. (BCIT)
Dobson, D.G.
Dorosh, L.W.; Dip. (BCIT)
Douglas, A.; B.Sc. (Victoria)
Earl, E.L.P.
Eaton, G.H.; Dip. (BCIT), B.Sc. (New Brunswick), C.L.S., P.Eng.
Fairfield, M.E.**
Farmer, P.M.
Fisher, D.L.
Galloway, J.L.; B.A.Sc. (EE), M.A.Sc. (EE) (Brit. Col.), P.Eng.
Gould, J.M.
Gresham, G.E.
Halcro, K.; Dip. (BCIT)
Hare, R.; Dip. (BCIT), C.L.S.
Hermiston, F.V.
Hinds, E.W.; Dip. (BCIT)
Hinds, S.D.*
Hohl, M.
Hollinger, C.; Dip. (BCIT)*
Holman, K.R.
Huggett, W.S.; Master (FG), C.L.S.
Jackson, D.M.; B.Sc. (Victoria)
Jackson, T.L.
Jennings, M.J.
Jodrell, D.A.
Johnson, B.A.; Dip. (BCIT)
Kenny, B.
Kerr, B.; Dip. (Seneca), B.A. (York)
Kidson, G.G.
Korhonen, R.K.
Larkin, J.B.; B.Sc. (Prince Edward Island)
Lee, K.S.
Lewis, B.V.; Dip. (BCIT)
Loschiavo, R.; Dip. (BCIT)
Lusk, B.M.; Master (350T), C.L.S.
Lyngberg, K.; Dip. (BCIT)
Lyon, A.G.
MacPhail, G.
Milner, P.R.; Dip. (BCIT)
Moody, A.E.***
Mortimer, A.R.; Master (FG), B.Sc. (Victoria), C.L.S.****
Muse, R.A.; Trade Cert. CAF
Nowak, C.; Dip. (BCIT)
Parkhouse, P.J.
Parks, J.R.; B.A.Sc. (EE) (Brit. Col.)
Pfluger, H.A.
Philp, A.R.
Pickell, L.M.
Pierce, R.A.
Popejoy, R.D.
Prince, D.W.; B.A. (Victoria)
Rapatz, W.J.; B.Sc. (Victoria), C.L.S.
Raymond, A.R.; Dip. (Algonquin)
Redman, D.
Richardson, G.E.; C.L.S.
Roberts, J.W.; Master (FG), Cdr. RCN (Ret'd)*
Ross, A.D.; CC (Ont. Inst. Chartered Cartographers)
Sadlish, J.P.
Sandilands, R.W.; Lt. (H) RN (Ret'd), C.L.S., FRGS
Sargent, E.D.; Dip. (BCIT)
Schlagintweit, G.E.; Dip. (BCIT)
Schofield, A.J.
Schofield, B.D.; B.Sc. (Victoria)
Smedley, A.J.; L. Cdr. RCN (Ret'd)
Smith, A.; Master (FG)
Smith, G.R.; B.A.Sc. (ME) (Brit. Col.), P.Eng.
Steeples, J.; Cert. Mech. Eng. (Edinburgh)
Stephenson, F.E.; B.Sc. (Victoria)
Taylor, W.R.
Thompson, L.G.
Thomson, A.D.; Dip. (BCIT)
Tuck, B.D.; B.Sc. (Victoria)
Vear, M.
Ward, M.M.; Dip. (BCIT), B.A. (Lakehead)
Watt, B.M.
Wells, I.C.; B.Sc. (Victoria)
Whincup, G.
Woods, M.V.; Dip. (BCIT), B.Sc. (Calgary)
Woodward, M.J.; B.Sc. (Victoria), M.Sc. (Toronto)
Woolley, R.; Dip. (BCIT)
Yee, J.

* Left in 1986/87
** Joined in 1986/87
*** Transferred to Ocean Physics
**** Seconded to Quebec Region

Ocean Physics

Division Chief:

Garrett, J.F.; B.A. (Harvard), Ph.D. (Brit. Col.)

Bell, W.H.*; B.A. Sc. (Brit. Col.), M.Sc. (Hawaii), P. Eng.
Bennett, A.F.; B.Sc. (Western Australia), M.S., Ph.D. (Harvard)
Bingham, R.W.
Budgell, W.P.; B.A.Sc. (Waterloo), M.Eng. (McMaster), Ph.D. (Waterloo)
Carmack, E.C.***; B.Sc. (Arizona State), Ph.D. (Washington)
Chase, G.W.; Dip. (BCIT)
Cooke, R.A.; Dip. (RCC)
Crean, P.B.; B.Sc. (Dublin), M.A.Sc. (Toronto), Ph.D. (Liverpool)
Cummins, P.F.**; B.Eng. (Concordia), M.Sc. (Brit. Col.)
de Jong, C.; Dip. (VMTO)
Delacretaz, A.
Farmer, D.M.; B. Comm., M.Sc. (McGill), Ph.D. (Brit. Col.)
Francis, D.B.; B.Sc. (Victoria)
Freeland, H.J.; B.A. (Essex), Ph.D. (Dalhousie)
Gargett, A.E.; B.Sc. (Manitoba), Ph.D. (Brit. Col.)
Gower, J.F.R.; B.A., M.A., Ph.D. (Cantab)
Henry, R.F.; B.Sc. (Edinburgh), Ph.D. (Cantab)
Holloway, G.; B.A.,M.S., Ph.D. (California)
Johnston, P.; Dip. (BCIT)
Kamitakahara, G.R.; B.Sc. (Toronto)
Koppel, A.W.
Kimber, P.M.
Lake, R.A.; B.Sc. (Brit. Col.), M.Sc. (Washington)
Lee, A.Y.P.; B.Sc. (Victoria)
Lewis, E.L.; B.Sc., M.Sc., Ph.D. (London)
Love, J.
Mathias, A.L.
Melling, H.; B.Sc., M.Sc., Ph.D. (Toronto)
Minkley, B.G.; Dip. (BCIT)
Miyake, M.; B.S. (EE) (Drexel), M.S., Ph.D. (Washington)
Moonie, J.A.
Moorhouse, S.W.
Murty, T.S.; B.Sc., M.Sc. (Andhra), M.S., Ph.D. (Chicago)
Perkin, R.G.; B.A.Sc., M.Sc. (Brit. Col.)
Pite, H.; B.Sc. (Victoria), Ph.D. (Sydney)
Quay, L.
Richards, D.L.
Spearing, L.A.F.; B.Sc. (Brit. Col.)
Stickland, J.A.
Stucchi, D.J.; B.A.Sc. (York), M.Sc. (Dalhousie)
Sudar, R.B.; B.A.Sc. (Toronto)
Tabata, S.; B.A., M.A. (Brit. Col.), D.Sc. (Tokyo)
Teichrob, R.C.; Dip. (BCIT)
Thomson, R.E.; B.Sc., Ph.D. (Brit. Col.)
Topham, D.R.; D.L.C., D.C.A.E., Ph.D. (Loughborough)
Wallace, J.S.; Dip. (SAIT)
Warnes, T.M.; Dip. (Camosun)

* Left in 1986/87
** Joined in 1986/87
*** On secondment from Nat. Hydrology Research Institute

Chemistry

Division Chief:

Wong, C.S.; B.Sc., M.Sc. (Hong Kong), Ph.D. (Scripps), Dip. Mar. Sc. (UNESCO), F.R.S. Chem. (U.K.), F.C.I.C.

Bellegay, R.D.; Dip. (NAIT), Assoc. Deg. in Oceanography (Shoreline Community College)
Cretney, W.J.; B.Sc., Ph.D. (Brit. Col.)
Henderson, J.G.
Johnson, W.K.; Dip. (BCIT)
Macdonald, D.M.; B.A.Sc. (Brit. Col.), Dip. (Camosun)
Macdonald, R.W.; B.Sc., Ph.D. (Dalhousie)
Mahood, H.[2]
McLaughlin, F.A.; B.Sc. (Victoria)
O'Brien, M.C.; B.Sc. (Alberta)
Paton, D.W.; B.Sc. (Brit. Col.)
Rogers, I.H.[2]; B.Sc. (Queen's, Belfast), M.Sc., Ph.D. (Brit. Col.)
Smith, G.L.; Dip. (NAIT)
Soutar, T.J.; Dip. (BCIT)
Thompson, J.A.J.; B.Sc. (McMaster), Ph.D. (Alberta), F.C.I.C.
Whitney, F.A.; B.Sc. (Brit. Col.)

[2]West Vancouver Laboratory

Ocean Ecology

(see Biological Sciences)

Data Assessment

Division Chief:

Wilson, R.C.H.; B.Sc. (Simon Fraser), M.S. (Western Washington)

Giovando, L.F.; B.A., M.A., Ph.D. (Brit. Col.)
Pitcher, J.A.*
Smiley, B.D.; B.Sc., M.Sc. (Alberta)

* Left in 1986/87

Biological Sciences

(Pacific Biological Station, Nanaimo, unless otherwise indicated)

Director:

Beamish, R.J.; Ph.D. (Toronto)

Thomson, J.A.; M.Sc. (McGill)
Steele, A.
Gignac, C.

Salmon and International

Section Head:

Bernard, F.R.; Ph.D. (London)

Ball, E.A.R.
Bams, R.A.; B.Sc. Hons., Nat. Phil. Drs. (Leyden)
Barner, L.W.
Beacham, T.D.; B.Sc. Hons. (Manitoba), Ph.D. (Brit. Col.)
Bigg, M.A.; Ph.D. (Brit. Col.)
Blackbourn, D.J.[7]; Ph.D.
Burke, M.
Carter, T.; Dip. Forest Tech. (Alberta)
Charles, K.
Chilton, D.
Christiansen, M.[1]
Cooke, K.; B.Sc. (Alberta)
Crabtree, D.
Dodds, D.; B.Sc. (Victoria)
Elder, C.A.
Gjernes, T.; B.Sc. (Brit. Col.)
Groot, C.; B.Sc., M.Sc. (Amsterdam), Ph.D.(Leyden)
Gulich, W.
Hargreaves, B.; B.Sc. (Alberta), Ph.D. (Dalhousie)
Henderson, M.[1]; Ph.D.
Holmes, M.
Holtby, B.; Ph.D. (Toronto)
Hudson, G.
Hungar, R.M.
Hyatt, K.; Ph.D. (Brit. Col.)
Irvine, J.[2]; B.Sc. Hons., M.Sc. (Brit. Col.), Ph.D. (Otago)
Janz, S.; B.Sc. (Alberta)
Jordan, F.P.
Kadowaki, R.K.; B.Sc. (McGill)
Kieser, R.; B.Sc. (Dalhousie), M.Sc. (New Brunswick), Ph.D.
Kuhn, B.
Lapi, L.; B.Sc. (Wisconsin), M.Sc. (Washington)
LeBrasseur, R.J.; B.Sc., M.Sc. (Brit. Col.), Ph.D. (Glasgow)
MacLellan, S.; B.Sc. (Brit. Col.)
McIlwaine, R.H.[1];
Miki, I.
Mulligan, T.J.; Ph.D. (Florida State)
Mundie, H.; Ph.D. (London)
Murray, C.B.
Nagtegaal, D.; B.Sc. (Simon Fraser)
Olesiuk, P.; B.Sc. (Manitoba)
Rankin, P.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Riddell, B.E.; B.Sc. (Guelph), Ph.D. (McGill)
Rutherford, D.; B.Sc. (Brit. Col.)
Rutherford, K.; B.Sc. (Victoria)
Schnute, J.; Ph.D. (Stanford)
Serbic, G.; Dip. (BCIT), B.Sc. (Brit. Col.)
Simpson, K.S.; B.Sc. (Simon Fraser), M.Sc. (Victoria)
Starr, P.[1]
Steer, G.
Thompson, R.A.
Traber, R.
Wilson, K.H.
Wood, C.C.; B.Sc. (Simon Fraser), Ph.D. (Brit. Col.)

Ocean Ecology (Institute of Ocean Sciences)

Division Chief:

Denman, K.L.; B.Sc. (Calgary), Ph.D. (Brit.Col.)

Brinkhurst, R.O.; B.Sc., Ph.D., D.Sc. (London)
Brown, R.M.; B.Sc. (Brit.Col.)
Forbes, J.R.; B.Sc. (Carleton), M.Sc. (Alberta)
Mackas, D.L.; B.S., M.S. (Washington), Ph.D. (Dalhousie)
Moore, D.F.; B.Sc. (McMaster)
Stone, M.

Fish and Health Parasitology

Section Head:

Margolis, L.; B.Sc., M.Sc., Ph.D. (McGill)

Baglo, P.
Bell, G.R.; B.S.A. (Brit. Col.), M.Sc. (Iowa State), Ph.D. (Western Ontario)
Bower, S.M.; B.Sc., M.Sc., Ph.D. (Guelph)
Evelyn, T.P.T.; B.S.A., M.S.A. (Toronto), Ph.D. (Brit. Col.)
Hoskins, G.E.; R.T. (R.C.H.), B.Sc. (Alberta)
Kabata, Z.; B.Sc., Ph.D., D.Sc. (Aberdeen)
Ketcheson, J.E.; B.Sc. (Alberta)
Kieser, D.; B.Sc., M.Sc. (Dalhousie)
McDonald, T.E.; B.Sc. (Brit. Col.)
Mullen, K.E.; B.Sc. (Victoria)
Prosperi-Porta, G.; Dip. Chem. Analyst, Paolo Parodi Delfino, Colleferro
Traxler, G.S.; B.Sc. (Washington)
Westby, C.M.; R.T., Can. Soc. Med. Technol. (BCIT)
Whitaker, D.J.; B.Sc. (Victoria)

Groundfish

Section Head:

McFarlane, G.A.; B.Sc. (Winnipeg)

Adams, D.; Dip. (BCIT)
Cass, A.; B.Sc. (Brit. Col.)
Davenport, D.
Fargo, J.; B.Sc. (Simon Fraser)
Foucher, R.P.; B.Sc. (Victoria)
Gillespie, G.E.; B.Sc. (Victoria)
Hand, C.M.; B.Sc. (Victoria)
Leaman, B.M.; B.Sc. (Simon Fraser), M.Sc. (Brit. Col.)
Leaman, J.E.
Lucas, J.[3]
Nott, J.M.; B.A. (UCD)
Richards, L.; B.Sc. Hons. (Dalhousie), M.Sc., Ph.D. (Brit. Col.)
Saunders, M.; B.Sc. (Victoria)
Scarsbrook, R.
Selsby, J.
Shaw, W.; B.Sc. (Victoria)
Smith, M.S.
Stanley, R.D.; B.Sc. Hons., M.Sc. (Brit. Col.)
Tyler, A.V.; B.A. (Pennsylvania), M.Sc., Ph.D. (Toronto)
Venables, N.L.[5]
Westrheim, S.J.
Winther, I.; B.Sc. (Victoria)

Herring

Section Head (Acting):

Haist, V.; B.Sc. (Brit. Col.)

Hay, D.E.; B.Sc. Hons., Ph.D. (Brit. Col.)
Haegele, C.W.; B.Sc. (Calgary)
McCarter, B.; B.Sc. (Brit. Col.)
Miller, D.; B.Sc. (Brit. Col.)
Roy, C.
Rosenfeld, L.; B.A. (Manitoba)

Schweigert, J.F.; B.Sc. Hons. (Toronto), M.Sc. (Manitoba)
Stocker, M.; B.Sc. (McGill), M.Sc. (Guelph), Ph.D. (Brit. Col.)

Habitat Capacity

Section Head:

Levings, C.D.[3]; B.Sc., M.Sc. (Brit. Col.), Ph.D. (Dalhousie)

Andersen, B.; B.Sc. (Brit. Col.)
Barnes, D.[6]
Birtwell, I.[3]; B.Sc. Hons. (London), Ph.D. (Kings College)
Brown, T.; B.Sc., M.Sc. (Simon Fraser)
Choromanski, E.[3]; M.Eng. (Szczecin)
Gordon, R.[6]; B.Sc. (Brit. Col.)
Hartman, G.; Ph.D. (Brit. Col.)
Kask, B.; B.Sc. (Victoria)
Kotyk, M.[3]; B.Sc. (Brit. Col.)
Kruzynski, G.[3]; B.Sc., M.Sc. (Sir George Williams), Ph.D. (Brit. Col.)
Lauzier, R.[3]; B.Sc. (Ottawa), M.Sc. (Simon Fraser)
Macdonald, J.S.[3]; Ph.D.
Mack, C.[6]
Martens, D.[6]; B.Sc. (Brit. Col.)
McAllister, C.D.; B.A., M.A. (Brit. Col.), Ph.D. (Washington)
Morell, S.[6]
Piercey, B.[3]; B.Sc. (Brit. Col.)
Price, D.[3]
Scrivener, C.; B.Sc., M.Sc. (Victoria)
Servizi, J.[6]; M.Sc. (M.I.T.), Ph.D. (Washington)
Shirvell, C.; B.Sc. (Alberta), Ph.D. (Otago)
Spohn, S.[3]; B.Sc. (Brit. Col.)
Waldichuk, M.[3]; Ph.D. (Washington)

Recruitment Mechanisms

Section Head:

Stockner, J.G.[3]; B.A. (Augustana), Ph.D. (Washington)

Enzenhofer, H.[6]; Dip. (BCIT)
Healey, M.C.; Ph.D. (Aberdeen)
Kennedy, O.D.
MacIsaac, E.[3]; B.Sc. (Brit. Col.)
Morris, J.
Morton, K.; B.Sc. (Brit. Col.)
Mueller, C.[6];
Shortreed, K.R.[3]; B.Sc. (Brit. Col.)
Stephens, K.
Tanasichuk, R.W.; B.Sc. Hons., M.Sc. (Alberta)
Ware, D.; B.Sc., Ph.D. (Brit. Col.)
Williams, I.[6]; B.Sc. (Brit. Col.)

Fish Culture Research

Section Head:

Donaldson, E.[3]; B.Sc. (Sheffield), Ph.D. (Brit. Col.), D.Sc. (Sheffield)

Alderdice, D.F.; B.A., M.A. (Brit. Col.), Ph.D. (Toronto)
Bagshaw, J.
Baker, I.J.[3]; Dip. (BCIT)
Ball, G.H.[4]
Blackburn, J.; B.A. (California)
Booth, M.[3]
Brouwer, D.
Clarke, C.; B.Sc. (Brit. Col.), M.Sc. (Toronto), Ph.D. (U.C., Berkley)
Damon, W.; B.Sc. (Brit. Col.)
Dye, H.M.; B.S.A. (Brit. Col.)
Fagerlund, U.M.H.[3]; M.Sc.
Higgs, D.A.[3]; B.Sc. (Victoria), M.Sc., Ph.D. (Manitoba)
Humphreys, R.M.
Hunter, G.; B.Sc., M.R.M. (Simon Fraser)
Jensen, J.; B.Sc. (Simon Fraser), M.Sc. (Washington)
Johnston, G.E.[4]
Kennedy, R.
Kreiberg, H.; B.Sc., M.Sc. (New Brunswick)
Lamb, A.[3]; B.Sc. (Brit. Col.)
Markert, J.R.[3]; B.Sc. (Brit. Col.)
McBride, J.R.[3]; M.A. (Brit. Col.)
Morley, R.; B.Sc. (Victoria)
Shelbourn, J.E.; B.Sc., M.Sc. (Brit. Col.)
Solar, I.[3]; B.Sc.
Solmie, A.
Tuck, D.; B.Sc. (Brit. Col.)
Velsen, F.P.
Withler, R.; B.Sc., M.Sc. (Brit. Col.)

Shellfish

Section Head:

Jamieson, G.S.; B.Sc. (McGill), M.Sc., Ph.D. (Brit. Col.)

Beg, T.
Bourne, N.; Ph.D. (Toronto)
Boutillier, J.; B.Sc. (Alberta), Teaching Cert. (Brit. Col.)
Carolsfeld, W.; B.Sc. (Victoria)
Fulton, J.; B.Sc. (Brit. Col.)
Harling, W.
Head, S.
Heritage, D.G.; B.Sc. (Victoria)
Noakes, D.; B.Sc. Eng. (Guelph), M.A.Sc., Ph.D. (Waterloo), P.Eng.
Phillips, A.; B.Sc. Hons. (Victoria)
Sloan, N.; Ph.D.
Whyte, J.N.C.; Ph.D. (Edinburgh)

Ships

Institute of Ocean Sciences

Parkinson, R.W.; Engineer 1st Class; Member, Institute of Marine Engineers
Fitch, L.A.H.; Master, H.T.
Craton, M.I.; Administrative Assistant
Doyle, D.A.; Secretary

CSS JOHN P. TULLY

Newton, B.L., Master; Master, F.G.
Pereira, P., Chief Engineer; Engineer, 1st Class
Coombes, A.S.; O.N.I
Gimbel, K.; O.N.II
Purdie, J.; W.K.M.
Stanway, J.D.; Engineer, 2nd Class

Heesterman, B.N.; Engineer, 3rd Class
Murphy, P.J.
Kirkby, D.
Garneau, G.C.
Law, S.
Keene, A.R.
Graham, D.B.
Aucoin, A.E.

Begin, P.
Boughton, D.G.
Napier, J.W.
Prunkl, W.J.
McRae, A.R.
Smart, T.R.
Brown, D.G.
Contois, W.M.

CSS PARIZEAU

Chamberlain, A.G., Master; Master, F.G.
Winterburn, G.E., Chief Engineer; Engineer, 1st Class
Anderson, J.M.; Master, F.G.
Elliott, H.G.; O.N.II
Garner, R.; Engineer, 2nd Class
Cooke, B.E.; Engineer, 4th Class
Waterfall, J.P.
Smith, J.R.
Springett, B.R.
Camiot, M.A.

Laforest, B.G.
Scott, R.C.
Fidler, M.J.
Green, J.S.
Palamar, V.
Waistell, G.A.
Kirk, M.J.
Keaveney, T.
Weston, A.
Begoray, N.
Hendrickson, L.A.

CSS VECTOR

MacKenzie, R.W., Master; O.N.I
Pearson, R., Chief Engineer; Engineer, 3rd Class
Wheeler, M.G.; O.N.I
Cadorin, G.D.; O.N.II
Macdonald, G.F.; Engineer, 4th Class
Lavigne, R.
Brown, J.D.

McKechnie, D.G.
Burns, R.G.
White, R.M.N.
Robie, D.J.
Simpson, F.W.
Fishes, P.R.
Anderson, D.D.

CSS RICHARDSON

Bishop, S.O., Master; Master, F.G.
Cruesemann, R.D.
Jamieson, T.A.

PISCES IV

Chambers, F.J., Chief Pilot
Taylor, R.H.
Oszust, J.A.

Witcombe, A.E.
Shephard, K.
Holland, R.R.

Institute Workshops

Smith, F.V., Supervisor
McNeill, J., Foreman
Bell, W.
Badminton, E.C.
Noreir, R.J.S.
Green, G.E.
Williams, P.D.
Ennis, J.F.
Smith, G.J.
Nelson, B.J.
Gurney, J.P.
Ingram, T.W.
Barlow, L.
Robson, W.J.
Thompson, B.R.***

Deck Machinery

Bradbury, J.D.

Shore Patrol and Relief Pool

Frost, P.A.; Master, F.G.
Campbell, J.O.; O.N.I
Knoblauch, D.E.; W.K.M.
Tran, K.H.; Engineer, 1st Class
Williams, L.E.R.; Engineer, 4th Class
Purdie, D.; Engineer, 2nd Class
Beebe, E.; Engineer, 4th Class
Simmons, B.R.; W.K.M.
Clark, R.W.
Allison, G.R.
Sanderson, R.L.
Lovelace, R.S.

Pacific Biological Station
Marine Support

Brennan, J.

FRV W.E. RICKER

Ranger, A., Master; Master F.G.
Fletcher, A., Fishing Master
Hardy, D., Chief Officer; O.N.I
Parfitt, D., 2nd Officer; O.N.I
Alford, E., 3rd Officer; W.K.M.
Swindell, J., Chief Engineer; Engineer 2nd Class
Dillon, R., Relief Chief Engineer; Engineer 2nd Class Motor
Baldwin, C., 3rd Engineer; Engineer 4th Class Combined
Stevens, W., 4th Engineer; Engineer 3rd Class Motor
Horbas, R.; Engineer 3rd Class Motor
Hunt, T.; Engineer 4th Class Motor
Labute, M.
Goodman, K.
McLennan, A.
Ford, R.
Ryan, E.
Duffin, D.
Judd, G.
McGladdery, F.
Hickey, R.
Culpepper, D.
Bellerose, E.
Ewing, A.
Blanchette, S.

FRV CALIGUS

Gregg, I., A/Master; Master H.T.
Wood, E.

*** Seconded to MOT

Computing
Institute of Ocean Sciences

Head:

Teng, K.; B.A.Sc., M.A. (Brit. Col.)

Douglas, A.N.; B.Sc. (Victoria)
Foreman, M.G.; B.Sc. (Queen's), M.Sc. (Victoria)
Green, J.W.; B.Sc. (Victoria)
Johns, R.E.; B.Sc. (Victoria), M.Sc. (Brit. Col.)
Lee, D.K.; B.S. (Chosun, Korea), M.S. (Oregon)
Lee, K.S.; B.Sc. (Victoria)
Linguanti, J.; B.Sc. (Victoria)
Ma, A.C.; B.Sc. (Victoria)
Oraas, S.R.; B.A.Sc., M.A.Sc. (Brit. Col.)
Page, J.S.; B.Sc. (Brit. Col.)
Smith, L.J.; B.Sc. (Simon Fraser)
Woollard, A.L.; B.Sc. (Victoria)

Biological Sciences

Head:

McKinnell, S.; B.Sc. (Victoria)

Hamer, M.; B.Sc. (Manitoba)
Hamer, T.
Marshall, M.; B.A. (Brit. Col.)

Communications Branch

Francis, K.L.; B.A. (Victoria) - PBS
Glover, K.T.; B.A. (New Brunswick) - IOS

Management Services Division
Institute of Ocean Sciences

Chief:
Coldwell, J.H.
Todd, N.A.; B.Sc. (Glasgow), M.A. (Carleton)*

Cooper, B.J.
Curtis, J.N.
Doxey, K.
Drysdale, A.E.

Gent, C.E.
Grills, C.J.
Hanmer, M.P.*
Hope, T.
Keding, L.M.
Kroeger, K.
Kusch, R.R.*
Lafortune, A.J.; B.A. (Manitoba)
Lapp, B.I.***
Loomes, L.**
MacMillan, B.C.
Oakfield, C.L.****
Sabourin, J.T.*
Smith, K.R.*
Thomson, L.S.C.; B.A. (Sask.), B.L.S. (Brit. Col.)
Tillie, D.G.
Van Eyk, W.J.

* Left in 1986/87
** Joined in 1986/87
*** Transferred to DFO, Prince Rupert
**** Transferred to MOT

Biological Sciences Branch

Chief:

Ross, W.B.; Dip. NBIT

Armstrong, C.
Bayntun, G.
Bolton, P.
Booth, B.; Engineer 4th Class
Chu-Joy, H.[2]
Coggins, S.
Hawthornthwaite, M.
Houlihan, C.
Humphreys, S.
Irving, P.
Keller, S.[2]
Matheson, R.[2]
McManiman, D.; Engineer 4th Class
Miller, G.; B.A. Hons. (Calgary), B.L.S. (Brit. Col.)
Muhlfellner, E.; Engineer 4th Class
Nagel, D.
Olson, P.; B.A. Hons. (Simon Fraser), M.L.S. (Brit. Col.)
Owen, D.
Palmer, M.
Parkin, S.
Parks, J.
Prior, J.***
Ranger, E.
Renner, T.; Engineer 2nd Class
Ring, P.; Engineer 3rd Class
Stead, L.; Engineer 4th Class
Strause, J.
Szablowski, R.*
Tuerlings, J.N.P.[2]
Vogt, P.
Williams, R.; Engineer 4th Class
Worthing, G.****

* Left in 1986/87
*** Transferred to DND
**** Transferred to IOS

Comptroller's Branch

Institute of Ocean Sciences

Lohrmann, B.A.; B.Sc., M.Sc. (Guelph), M.P.A. (Victoria)

Biological Sciences Branch

Arbanas, M.

Ganderton, M.
Muermann, B.
Reynolds, B.***
Sherry, M.
Sloan, D.*
Varga, Y.

* Left in 1986/87
*** Transferred to IOS

Personnel Branch
Institute of Ocean Sciences

Regional Manager:

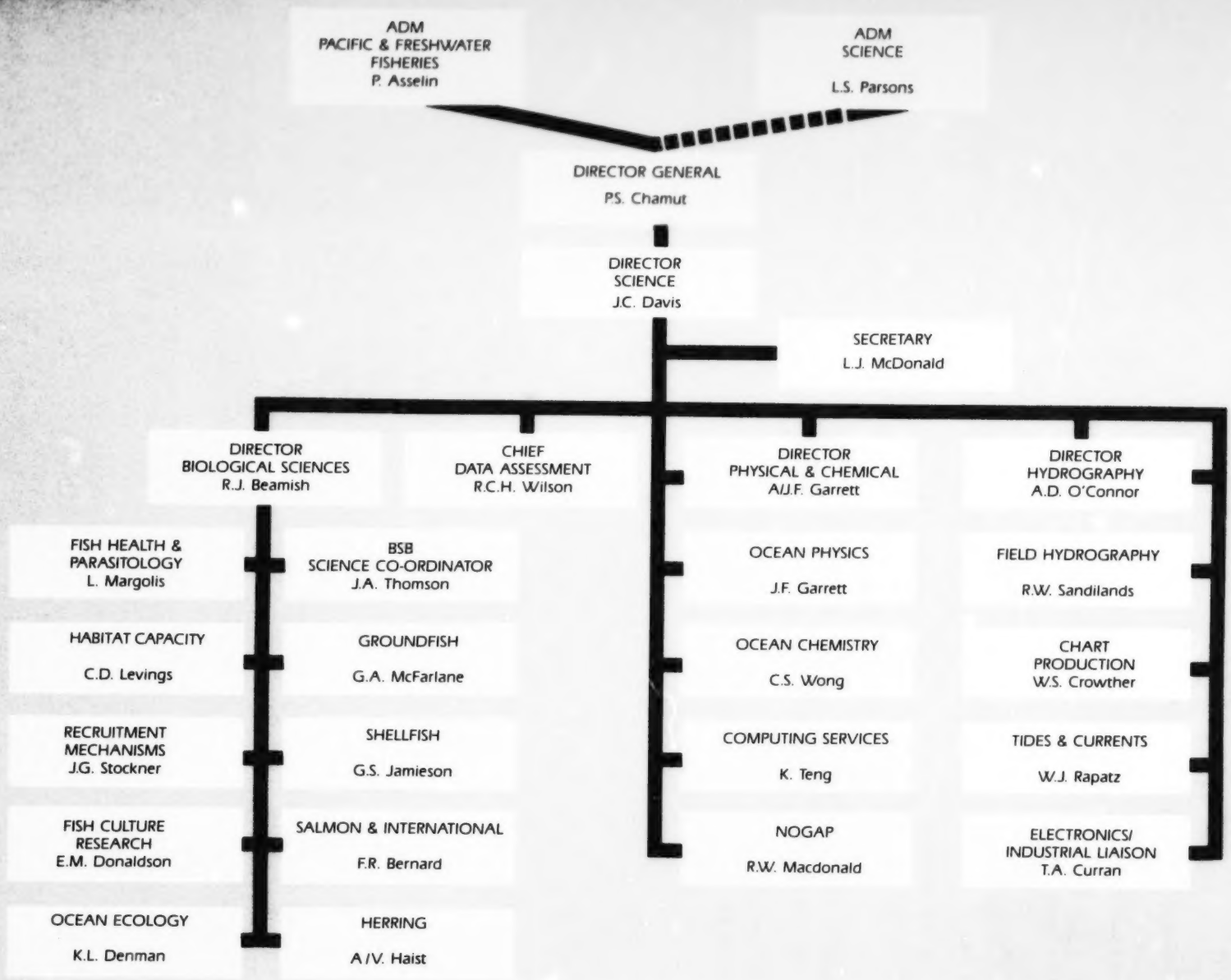
Hamilton, K.R.; B.A. (Brit. Col.)

Groves, L.D.; Dip. (Victoria)
Knapp, B.M.
Linguanti, S.C.
Olauson, E.J.
Renstrom, M.
Pritchard, E.

Biological Sciences Branch

Ford, D.

[1]DFO Headquarters, Vancouver
[2]West Vancouver Laboratory
[3]Prince Rupert
[4]Rosewall Creek
[5]Vancouver waterfront
[6]Cultus Lake
[7]New Westminster
[8]Institute of Ocean Sciences

ORGANIZATION CHART

Department of Fisheries and Oceans
Science, Pacific Region